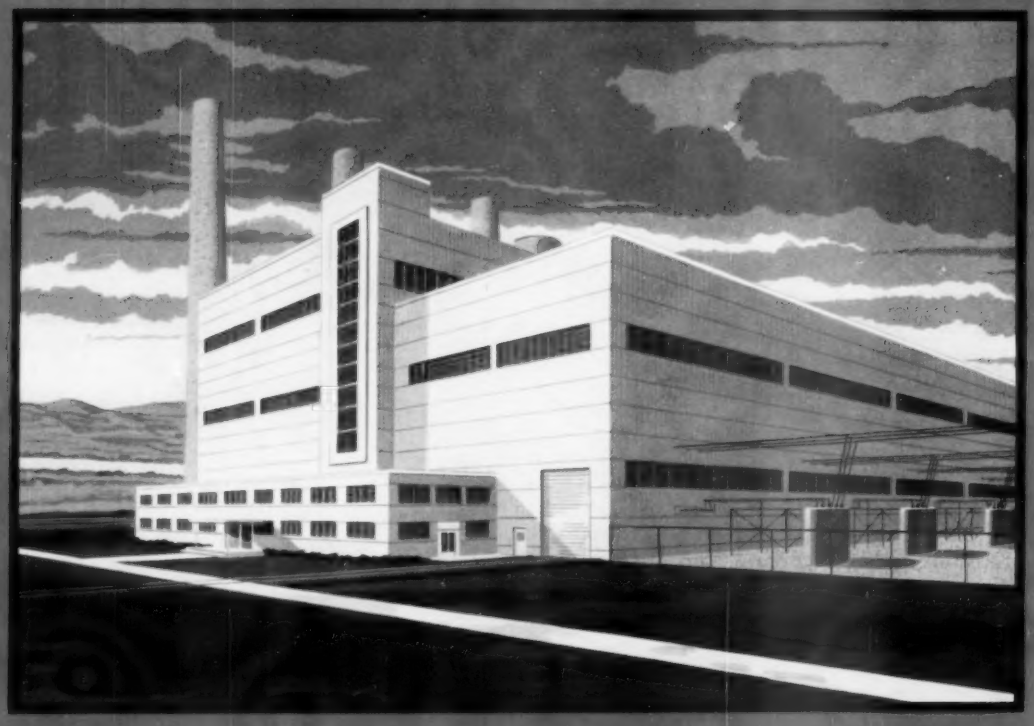
COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

November 1957



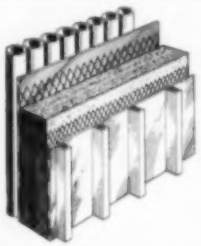
Artist's conception of the Southern Electric Generating Co.'s eventual 1,000,000 kw steam electric plant to be built on the Coosa River, Alabama

Selection and Application of Cooling Towers

Flow of Coal In Bins

Incremental Maintenance Costs

Eighteenth Annual Water Conference

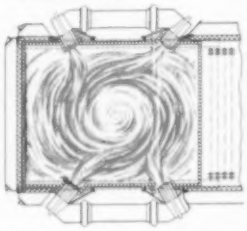


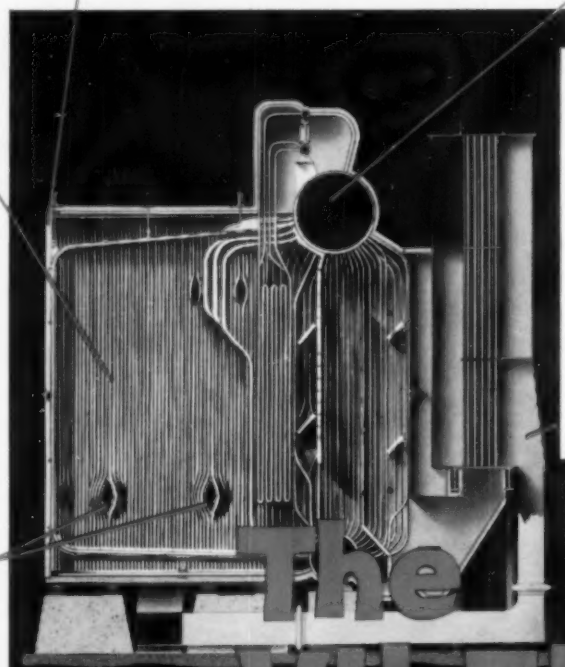
DOUBLE WALL, PRESSURE-TIGHT CASING. The latest development in casing construction for pressure firing of boilers in the size class of the VU-55, this casing is designed to assure life-time tightness with minimum heat loss. Pressure firing permits the elimination of an induced draft fan with its attendant operating and maintenance costs. Construction consists of tangent tubes backed up successively by welded steel panels, 4 inches of high quality insulating material and an outer steel casing formed as shown to provide adequately for expansion and assure ample strength. Low heat loss and the tightness required for pressure firing are assured by this double-wall construction.

HIGH STEAM QUALITY. Equipped with a large (60-in.) steam drum, the VU-55 has generous water capacity and steam reservoir space. C-E drum internals assure high quality steam at all ratings.

TANGENT FURNACE TUBES. The VU-55's furnace tube arrangement provides complete heat-absorbing, water-cooled protection on all furnace walls. Furnace maintenance is minimized, refractory expense is eliminated, heat absorption rates per sq. ft. are higher.

TANGENTIAL FIRING. More than 20 years of application experience have established the exceptional advantages of tangential firing. About 90 per cent of Combustion's large utility installations use this advanced method of firing. Flame streams from the four burners impinge upon one another at high velocity, as shown, creating a turbulence unattainable by any other method of firing. The result is rapid and complete combustion. As the gases spiral upward, they sweep all furnace heating surfaces, assuring a high rate of heat absorption.





STREAMLINED EXTERIOR. The over-all appearance of the VU-55 reflects the efforts of its designers to achieve a completely unobstructed casing, while retaining adequate access wherever required and every facility for convenient operation. There are no outside downcomer tubes, and ducts from the air heater to the burners are located beneath the furnace floor.

The VU-55 Boiler...

Custom Features, Standard Sizes, Advanced Design

The VU-55, newest of the C-E line of Vertical Unit Boilers, represents the closest approach to central station performance yet achieved in standardized boilers in its capacity range.

Its design combines a number of time-tested and service-proved features, such as Tangential Burners, double wall, pressure-tight casing, and tangent furnace tubes. In addition, this bottom-supported unit requires no outside supporting steel, is economical of space and streamlined in appearance.

It is available in 5 sizes for capacities from 50,000 to 120,000 lb per hour. It is designed for 3 pressure ranges (250, 500 and 750 psi) and can be equipped with a superheater to provide temperatures up to 750 F. Either a tubular or a regenerative air heater is available.

The VU-55 Boiler is symmetrical in design, performs efficiently over a wide range of output, and is easy to operate and maintain.

It is, in fact, the boiler with the custom features and the advanced design.

COMBUSTION ENGINEERING

Combustion Engineering Building • 200 Madison Avenue, New York 16, N. Y.

Canada: Combustion Engineering-Superheater Ltd.

C-E

B-978A

all types of steam generating, fuel burning and related equipment; nuclear reactors; paper mill equipment; pulverizers; flash drying systems; pressure vessels; soil pipe.

COMBUSTION

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Vol. 29 **No. 5**

November 1957

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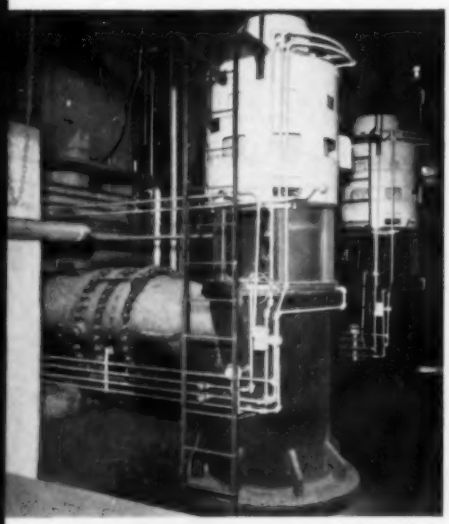
BPA

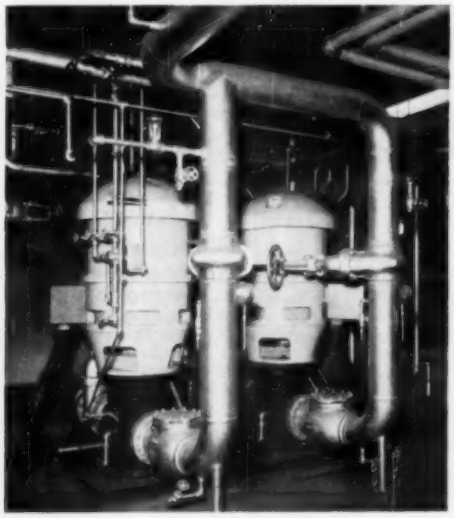
Printed in U. S. A.

Ingersoll-Rand
power plant equipment

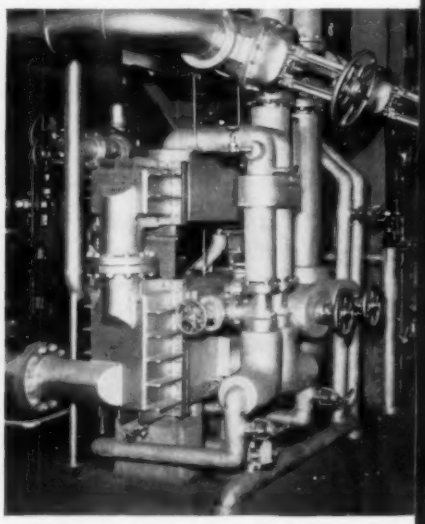
CONDENSER. Space-saving Ingersoll-Rand rectangular condenser, with 75,000 sq ft of cooling surface, serves the bottom-exhaust steam turbine for the 100,000-kw generating unit at this large, modern steam plant.



CIRCULATING PUMPS. Two Ingersoll-Rand Class APM vertical circulating pumps, each with capacity of 32,500 gpm, handle the condenser cooling water.



CONDENSATE PUMPS. The condenser is also served by two Ingersoll-Rand Class APHC vertical hot-well pumps, each handling 1400 gpm of condensate.



STEAM-JET EJECTOR. This Ingersoll-Rand two-stage steam-jet ejector is used to evacuate the condenser of all air and non-condensible gases.

How Another Central Station Profits with

MATCHED PERFORMANCE

of POWER-PLANT EQUIPMENT

by Ingersoll-Rand

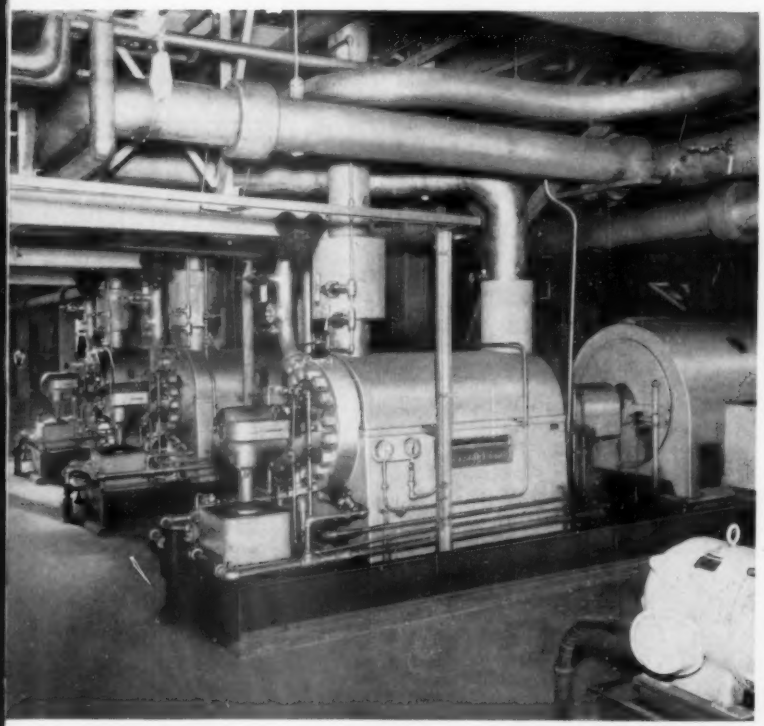
All of the Ingersoll-Rand equipment shown here is installed in a single large utility steam plant.

The condenser, circulating pumps, condensate pumps, ejectors and boiler-feed pumps are designed and built for matched performance — matched to each other and to the job. Functional coordination of these elements is vital to the economy and continuity of the steam generating cycle. And by entrusting the undivided responsibility for their design and construction to I-R power plant equipment specialists, the user is assured of maximum efficiency and dependability in continuous, heavy-duty service.

The compressed air equipment, too — for soot blowing and instrument air — plays an important role. Although basically unrelated to each other, these compressors are matched to the job — designed to give top performance and economy under actual plant conditions.

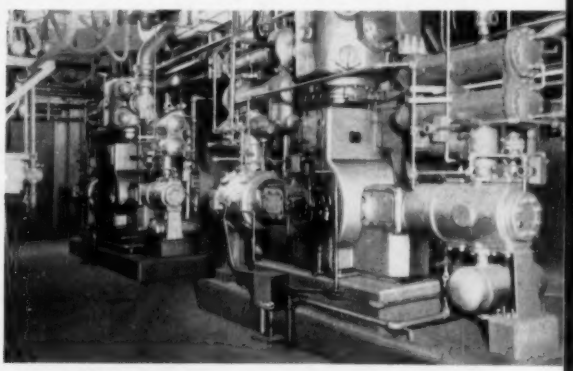
Whatever your power plant requirements — for condensers, pumps, vacuum equipment and compressors — be sure to contact your Ingersoll-Rand representative. His specialized experience in product and application engineering can save you time, effort and expense in meeting your exact requirements to best advantage. Ingersoll-Rand, 11 Broadway, New York 4, N. Y.

14-679

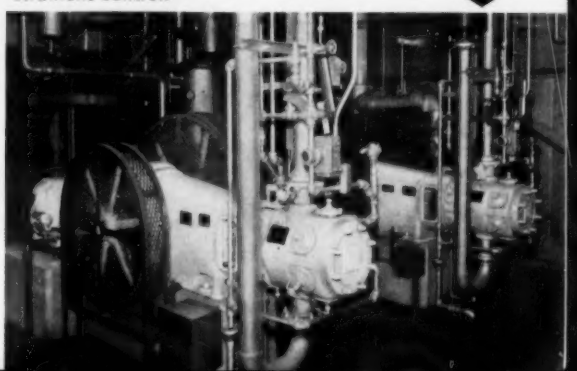


BOILER-FEED PUMPS. Three Ingersoll-Rand Class CHTA boiler-feed pumps, with double-case construction and "unit-type" rotor assembly, each handle 990 gpm at 2300 psi discharge pressure.

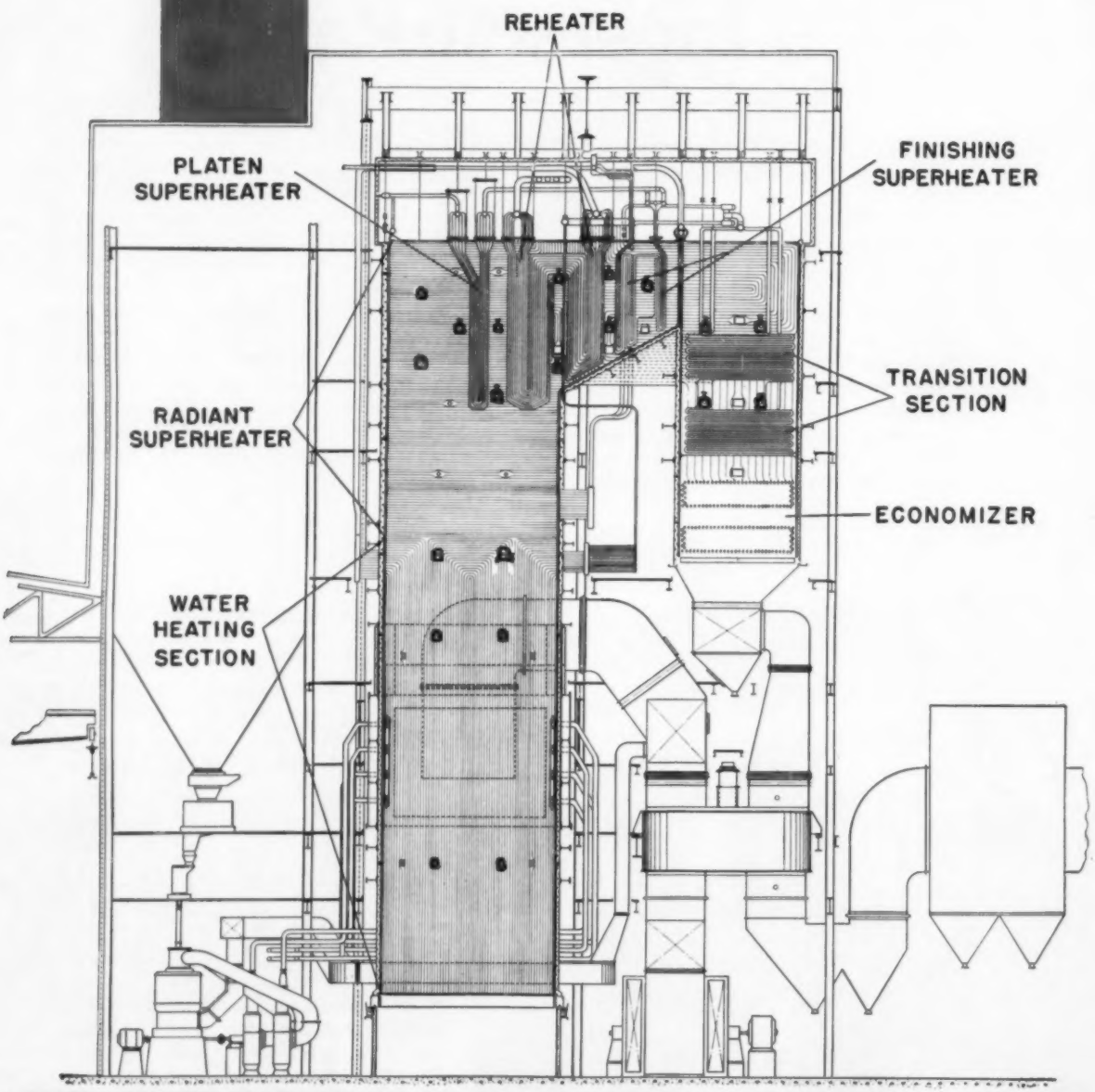
SOOT BLOWING COMPRESSORS. Two I-R three-stage TVH compressors with direct-connected motor drive provide high-pressure air for soot-blowing.



INSTRUMENT AIR. Two I-R ES-NL compressors with non-lubricated cylinders provide oil-free air for instrument control.



Vulcan Selective-Sequence System picked for



The Cleveland Electric Illuminating Company
Avon Station Turbine Unit #8—Boiler #11
CE Sulzer Design
Boiler Capacity—1,715,000 lbs. per hour
Turbine Capability—250,000 KW
Steam Conditions at Turbine Throttle—3500 PSIG—1100F—1050F

Soot Blowing Avon Station

The Cleveland Electric Illuminating's new super-critical pressure unit at Avon Station will be equipped with Vulcan T-3-E long retractable soot blowers, RW-3E wall deslaggers and air-preheater cleaning controls. Blowing medium will be air with emergency steam stand-by—from existing boilers. Air will be furnished by a centrifugal air compressor. Selective-sequence control will provide precisely the sequence necessary for the most effective cleaning. Blowing sequences can be varied from a compact, pre-wired control board simply by means of patch cords. Thus, any blower can be operated at any point in the sequence. The entire cycle can be set to run automatically to completion, to recycle or to operate under clock control.

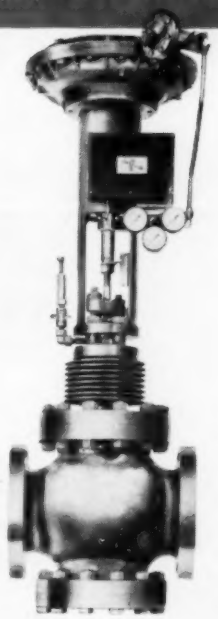
Modern Copes-Vulcan soot blowing systems such as the selective-sequence to be installed at Avon Station can help to keep your boilers operating at peak efficiency. Your Copes-Vulcan representative has the ideas, information and experience to help you make the selection best suited to your operation.

COPES VULCAN

BLAW-KNOX

COPES-VULCAN DIVISION
BLAW-KNOX COMPANY
ERIE 4, PENNSYLVANIA

C-V NEWS NOTES

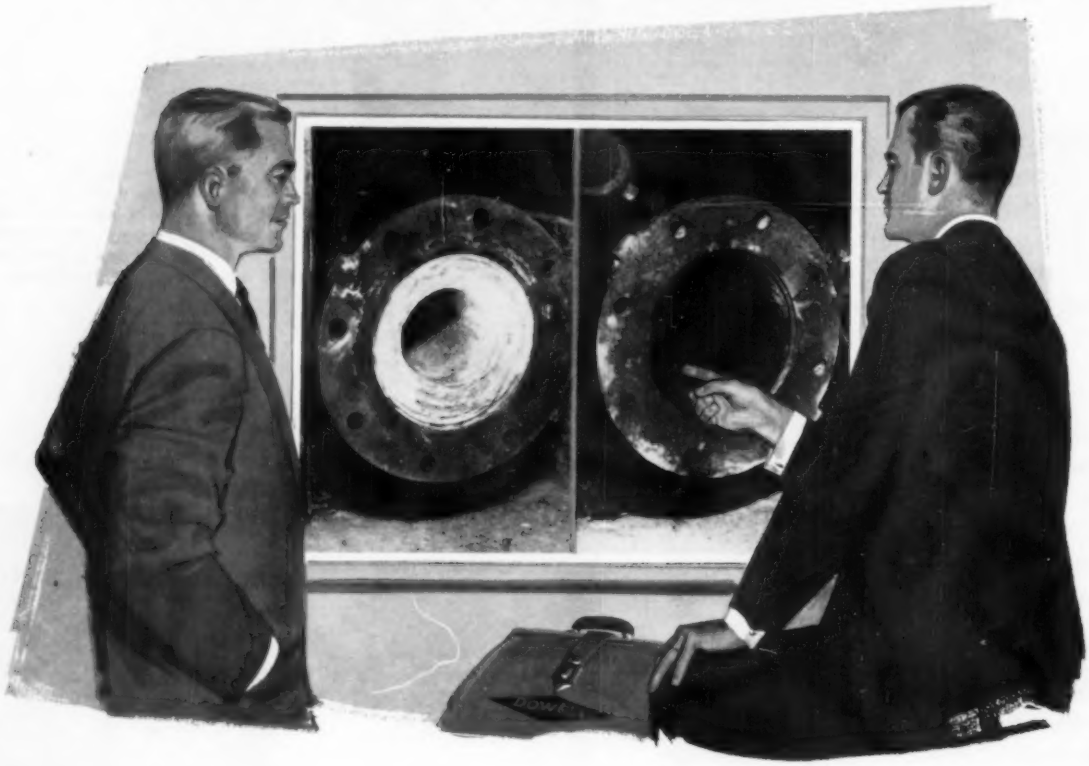


New Copes-Vulcan diaphragm-type CV-D valves have high rangeability, are either reverse or direct acting. They can be applied in sizes up to 12 inches at unlimited pressures.

Copes-Vulcan boiler control at Louis V. Sutton Steam Electric Generating Plant of Carolina Power & Light Company is described in Bulletin 1032. Your Copes-Vulcan man has a copy for you, or you may wish to write direct.

Unit 8 at Avon Station will get Copes-Vulcan pressure reducing and desuperheating station for energizing back-up soot blower steam supply. Copes-Vulcan desuperheaters will provide close control for all loads from 0 to 45,000 pounds per hour, with virtually instantaneous cycling.

here's how Dowell chemical cleaning saved $71,000 and helped protect a plant profit!



A few months before their peak season, the operators of this plant decided their main water line might not supply the water necessary to meet peak demands. The line was cast-iron, 16-inches in diameter and over 7,000 feet long. Its original flow efficiency or "C" factor had been 105; scale build-up had reduced this to 72. To lay an auxiliary line would cost at least $85,000.

Dowell contracted to clean the pipe chemically for a little less than $14,000, and to restore a minimum of 50 per cent of the line's lost capacity.

This Dowell did, and more—increasing the "C" factor to 92! Enough water was immediately available for capacity operation. This saved the plant $71,000 and helped protect the company's annual profit.

The operating credit realized by this food processing plant, as a result of Dowell service, is similar to those realized by other Dowell customers—in the steel, paper, chemical, oil refining, power and allied industries.

Dowell engineers are experts in the use of solvents to remove scale and sludge—deposits that cut the throughput of product, process and steam generating systems. Dowell does the job, furnishing all chemicals, trained personnel, pumping and control equipment.

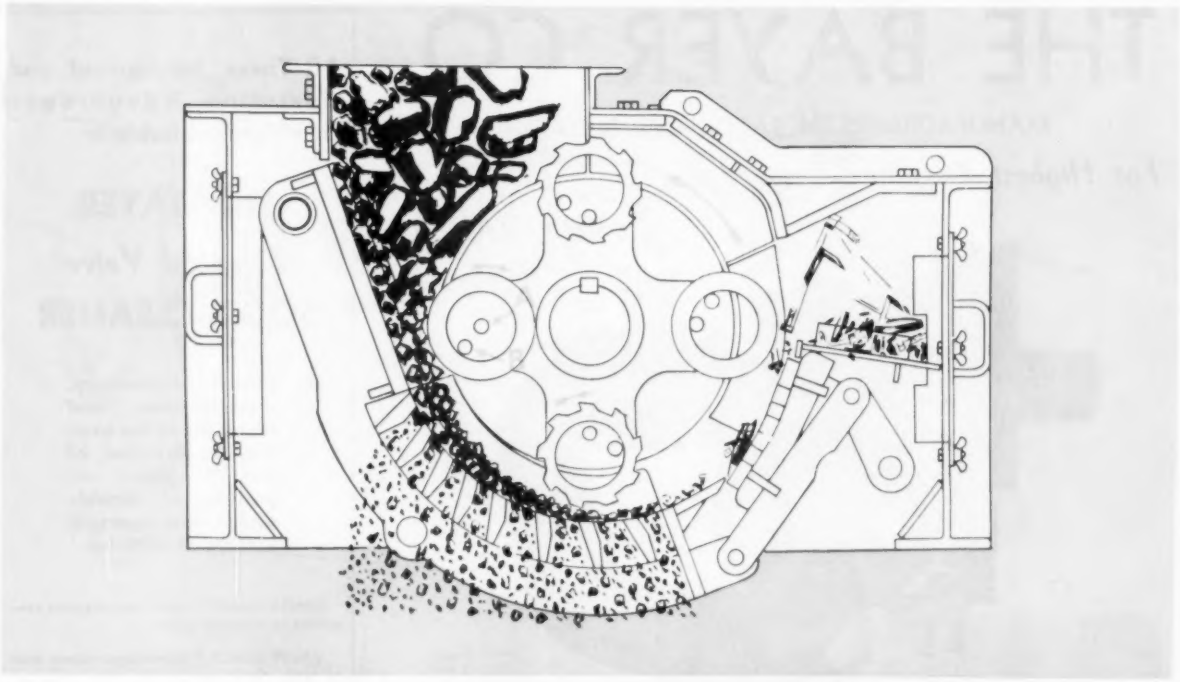
For specific information on how chemical cleaning can help you to greater profits, call the Dowell office nearest you. Or write Dowell Incorporated, Tulsa 1, Oklahoma.

25 years forward

Have Dowell clean it chemically

DOWELL

A SERVICE SUBSIDIARY OF THE DOW CHEMICAL COMPANY



This original Pennsylvania crushing action, whereby snubbed down rings* roll slowly across the feed with a constant intense pressure, cracks the coal into uniform granular pieces with a *minimum of fines.* The Pennsylvania Coal Granulator produces a premium product that protects against stoker and pulverizer overload, loss of fuel through overgrinding and coal segregation on stokers. That's the big difference in these proven Coal Granulators—the product they produce. And after all, that's what you are really buying in the long run, not just capacity, but specified capacity of a product that's superior to what other crushers produce. To learn more about the features that set Pennsylvania Coal Granulators way out ahead, send for bulletin 9003. And remember, the greatest developments in crusher design are still coming from Pennsylvania!

* see A and B in above illustration.

PENNSYLVANIA CRUSHER DIVISION
Bath Iron Works Corporation
West Chester, Penna.

GRANULATION
the economical method of coal reduction for Stokers and Pulverizers
•
MUCH LESS OVERGRINDING

PENNSYLVANIA

COAL GRANULATORS

PE-249

THE BAYER CO.

MANUFACTURERS OF BAYER SOOT BLOWERS

For Highest First and Final Value

. . . BUY BAYER!

BAYER

Balanced Valve

SOOT CLEANER

Bayer's single-chain design compels perfect in-step operation of valve and element. Operation is positive, definite, assuring a full flow of steam for efficient cleaning.

When the operator pulls chain, the cam-actuated, quick-action balanced valve is opened. By continued pulling of the chain, worm drive slowly rotates element over cleaning arc. When element reaches end of cleaning arc, valve automatically closes.

Minimum steam consumption—low maintenance. Every detail is engineered, built for long life, efficient performance at high temperatures and high pressures.

More than 30,000 boilers are Bayer equipped. More than 45 years' successful, specialized experience assures you investment economies in Bayer equipment.

QUALIFIED LOCAL ENGINEERING SERVICE—Your Bayer representative is an experienced engineer, well qualified to take care of any service needs in connection with Bayer Soot Cleaners. He is available when you call upon him and will gladly render any service required.

All These Mechanical and Operating Advantages are available in

The BAYER *Balanced Valve* SOOT CLEANER

1. **Sound engineering, workmanship, and materials of the best.**
2. **An organization of over 45 years' experience, capable and willing to render service at all times.**

SINGLE CHAIN: Valve and element controlled by a single chain.

VALVE BODY: Rugged construction, built to last. Short and ample steam passage giving very small pressure drop.

ORIFICE PLATE VALVE: For high pressure service, each head may be controlled by an orifice plate valve through which pressure is adjusted for each individual element.

STUFFING BOX: Due to maintenance of perfect alignment on swivel tube, packing needs little attention. Stuffing box is in full view, readily accessible.

AIR SEAL: Has machined surface on wall sleeve and spring-held floating seal to prevent air in-leakage.

HEAD BEARINGS: There are two main bearings, an outboard and an inboard bearing for the swivel tube to maintain alignment.

THRUST BEARING: Ring type thrust bearing takes the load.

VACUUM BREAKERS: Two vacuum breaker air valves, or one valve and a signal whistle above each valve, to prevent suction of boiler gases into valve and piping.

ELEMENT OPERATION: With the Bayer element operation, balanced valve is opened just as element rotates, giving FULL pressure over entire cleaning arc. Full steam pressure insures thorough cleaning. Balanced valve saves wear of valve parts. With any type of poppet valve, this is important...ask any operator.

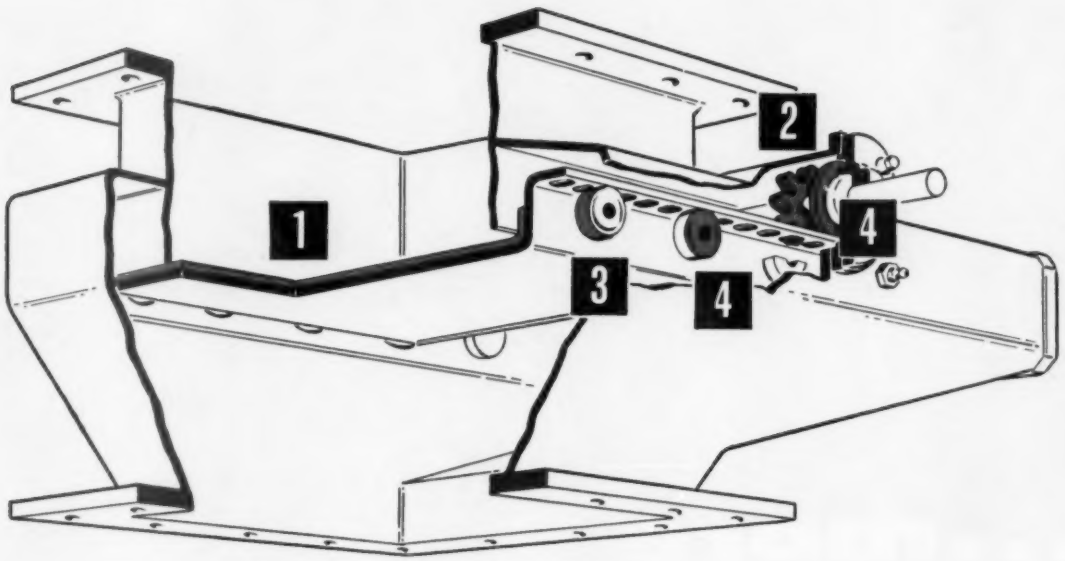
BLOWING ARC: Valve cams automatically regulate cleaning arc.

REDUCTION GEARS: 24 to 1 gear ratio gives slow rotation for good cleaning.

FLANGED PIPE CONNECTION: Operating head is connected to supply pipe by flanges and through bolts, or high tensile studs and nuts.

THE BAYER CO.

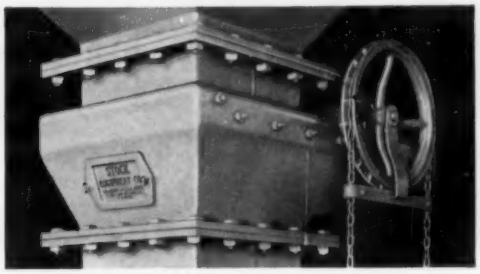
St. Louis, Mo.



The inside story

ON THE S·E·CO COAL VALVE . . .

STAINLESS STEEL



Wherever you find coal you find corrosion—or the possibility of corrosion. And wherever you find corrosion you find valves that stick, are hard to operate and that will soon need replacement.

Stainless steel resists corrosion — makes valves that are easy to operate and that have a much longer life. That's why Stock Equipment Company has made stainless steel a *standard material* for certain vital parts of the S-E-Co. Coal Valve.

Take the deep U-shaped gate, for instance. The stainless steel liner (1) on top combats corrosion. This not only means longer life, but by preventing pitting it reduces friction when closing against a head of coal.

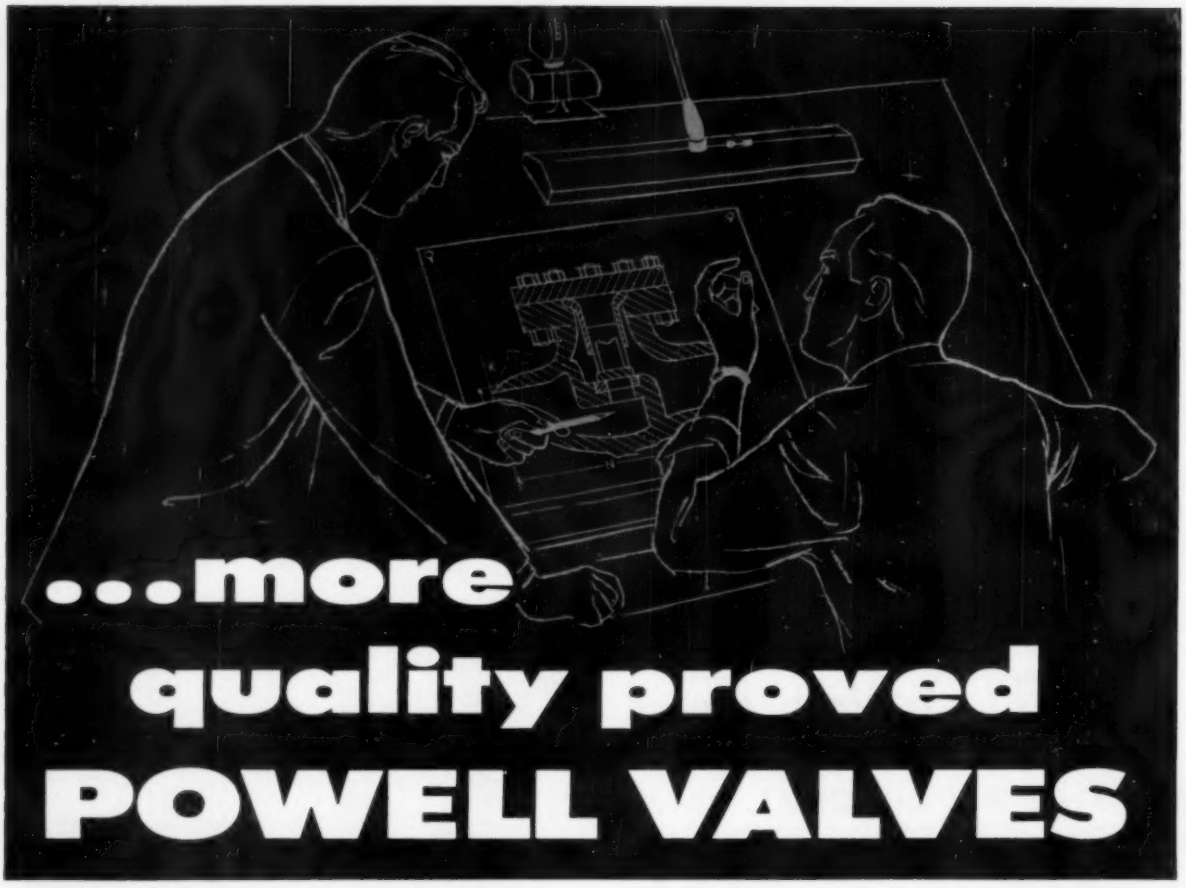
Multi-faced pinions (2) located above the self cleaning racks are also of stainless steel. By withstanding corrosion the thin pinion sections maintain their strength and are thin enough to make racks and pinions truly self-cleaning.

In addition, stainless steel is used for the shells of the gate-supporting rollers (3) and for the grease seal retainer rings on roller and shaft bearings. (4).

For dependable, efficient valve operation, get S-E-Co. Coal Valves which feature stainless steel as a standard material. If you have a particularly severe problem of corrosion, Stock Equipment Company can help insure normal operation and long life by making the valve body itself entirely of stainless steel.

STOCK Equipment Company

745-C HANNA BLDG. • CLEVELAND 15, OHIO



...more quality proved POWELL VALVES

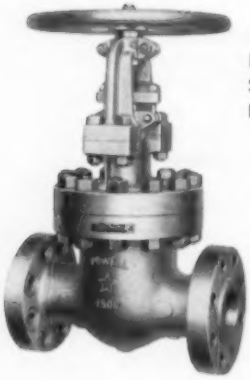


FIG. 1303 SS—1500-Pound Stainless Steel Gate Valve for handling Boiler Feed Water Treating Compound.

FIG. 3061 WE—300-Pound Steel Swing Check Valve.

FIG. 1314 A—1500-Pound Integral Bonnet Steel "Y" Valve.

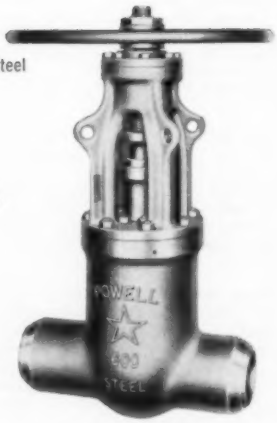


FIG. 16003 WE—600-Pound Steel Pressure Seal Gate Valve.

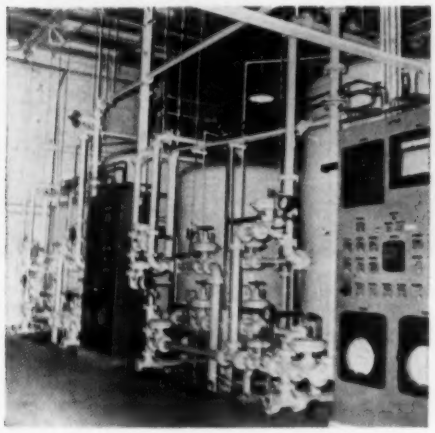
Designed for long life, designed for dependable service

Consult your Powell Valve distributor for all the facts about quality proved bronze, iron, steel and corrosion-resistant valves. No matter what the flow control problem, a Powell Valve can solve it . . . *better.*

THE WM. POWELL COMPANY, CINCINNATI 22, OHIO . . . 111th YEAR

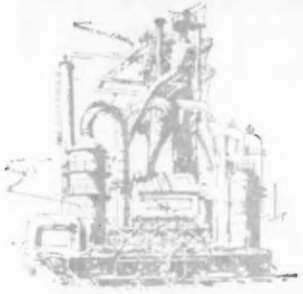
First in water conditioning

Installation below is a large paper mill. It provides an effluent with silica content below 0.02 ppm and total dissolved solids below 1.0 ppm. Total capacity 100,000 lbs/hr. for 1200 psi boiler.



Cochrane DEMINERALIZERS

for efficient silica and solids reduction



Many of America's outstanding high-pressure steam generating plants are protected by Cochrane Demineralizers. The quality of demineralized water is superlative and Cochrane's progress in solving the many problems associated with demineralization is attested to by some of the largest installations in the world.

Cochrane's untiring staff of chemists, engineers and research men assure you of the answer to your water conditioning problem and continued satisfactory operation of your Cochrane installation.

Why not investigate the impressive list of Cochrane 2-bed, 3-bed, 4-bed and mixed bed Cochrane Demineralizer installations? For the answer to your water conditioning problems consult Cochrane's complete service first. Ask for Bulletin 5800.

Cochrane
CORPORATION
3109 N. 17TH STREET, PHILADELPHIA 32, PENNA.
NEW YORK • PHILADELPHIA • CHICAGO
Cochrane Water Conditioning Ltd., Toronto 4; Montreal 1, Canada
Representatives in 30 principal cities in U.S.; Paris, France; La Spezia, Italy; Mexico City, Mexico; Havana, Cuba; Caracas, Venezuela; San Juan, Puerto Rico; Honolulu, Hawaii; Manila, Philippine Islands.
Pottstown Metal Prods. Div.—Custom built carbon steel and alloy products.

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Demineralizers • Zeolite Softeners • Hot Process Softeners • Hot Lime Zeolite Softeners • Dealkalizers • Reactors • Deaerators • Pressure Filters
Continuous Blowoff Systems • Condensate Return Systems • Steam Specialties

THE CROSS COMPANY—Fraser, Michigan
Consulting Engineers, Giffels & Vallet, Detroit, Michigan

Installed at this new ultra-modern plant are two 12-million BTU capacity C-E Hot Water Boilers. When this pioneer producer of automation equipment studied their heating requirements, they calculated that this system would provide the lowest fuel and maintenance costs. Their actual winter operating experience proved the soundness of this decision.

CONVAIR-ASTRONAUTICS—San Diego, California
Consulting Engineers, Pereira & Luckman

When this division of the General Dynamics Corporation determined that more space was needed for their Atlas Intercontinental Ballistic Missile project, this new center for research, development, manufacturing, and primary testing of the Atlas was decided upon. Installed in this center of space flight research will be two 30-million BTU C-E Hot Water Boilers.

HIGH TEMPERATURE

ADVANTAGES

—of high temperature water:

1. Higher available heat—many times that of steam at the same pressure.
2. Closer control of temperature.
3. Lower heat loss . . . unused heat returns to the boiler . . . no condensate return lines.
4. No elaborate feedwater treatment . . . make-up requirements are exceptionally low.
5. Steam traps not required . . . trap problems and expense are eliminated.
6. No blowdown losses . . . no safety valve vent losses . . . no condensate losses.

—of the C-E Hot Water Boiler:

1. Complete control of circulation in system and boiler.
2. No separate boiler pump needed . . . pressure loss is low.
3. Pressurized operation with oil or gas means no induced draft fan.
4. Single-pass design—no baffles—means cleaner boiler and lower draft loss.
5. Controlled, positive circulation permits more efficient arrangement of heating surfaces.
6. Any fuel—oil, gas, coal, or any combination of fuels.
7. Gas-tight, welded steel casing.
8. Fewer headers, all of which are easily accessible.

COMBUSTION

Combustion Engineering Building

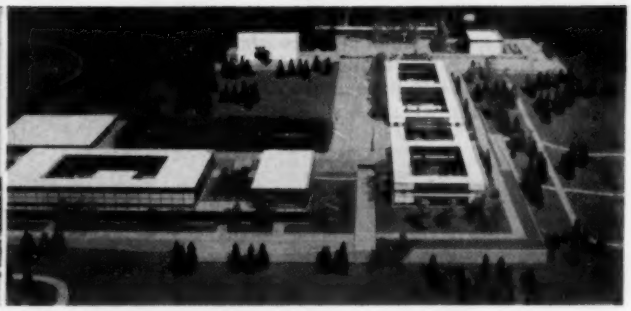
CANADA: COMBUSTION ENGINEERING-

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT; NUCLEAR REACTORS;

RIVERVIEW COMMUNITY HIGH SCHOOL—Riverview, Michigan
Consulting Engineers, Bennett & Straight, Detroit, Michigan

To keep pace with the expanding need for more educational facilities, Riverview, Michigan has recently finished this fine, modern high school. Its heating requirements are met by two 10-million BTU C-E La Mont Controlled Circulation Hot Water Boilers.

U.S. AIR FORCE ACADEMY—Colorado Springs, Colorado
Consulting Engineers, Skidmore, Owing & Merrill



Typical of our Air Force's widespread acceptance of high temperature water for various of their installations is the selection of five C-E Hot Water Boilers for their new academy. These units will furnish heat for living, academic, and service areas here.

WATER today's new idea in large-space heating

In such diverse applications as industrials, large educational institutions, and military bases, high temperature water is finding rapidly increasing acceptance as an ideal means of heating large areas.

A big factor in bringing this trend about is The C-E La Mont Controlled Circulation Hot Water Boiler. Using the same principle as that applied by C-E in many of the country's largest utility boilers, this new boiler provides a degree of temperature control that makes it the most attractive method of heating in many cases. With a wide range of capacities – from 10 to 300 million Btu's – these boilers operate at water pressures up to 500 psi and temperatures to 470F, or higher. Depending upon local conditions, a C-E Hot Water Boiler can save from 10 to 20 per cent in maintenance and operating costs.

The smaller capacity Hot Water Boilers are completely shop assembled, while the intermediate and large units are shipped in varying stages of assembly. This C-E practice greatly reduces erection costs.

So, if you are in the market for boilers, either for space heating or process requirements, it may prove greatly to your advantage to investigate the use of high temperature water as your heat source. Because individual needs vary, both steam and hot water have their place. Our engineers will be pleased to discuss either method with you or your consultants –impartially and with no obligation.

For further details on high temperature water boilers by C-E write for our catalog HCC-2.

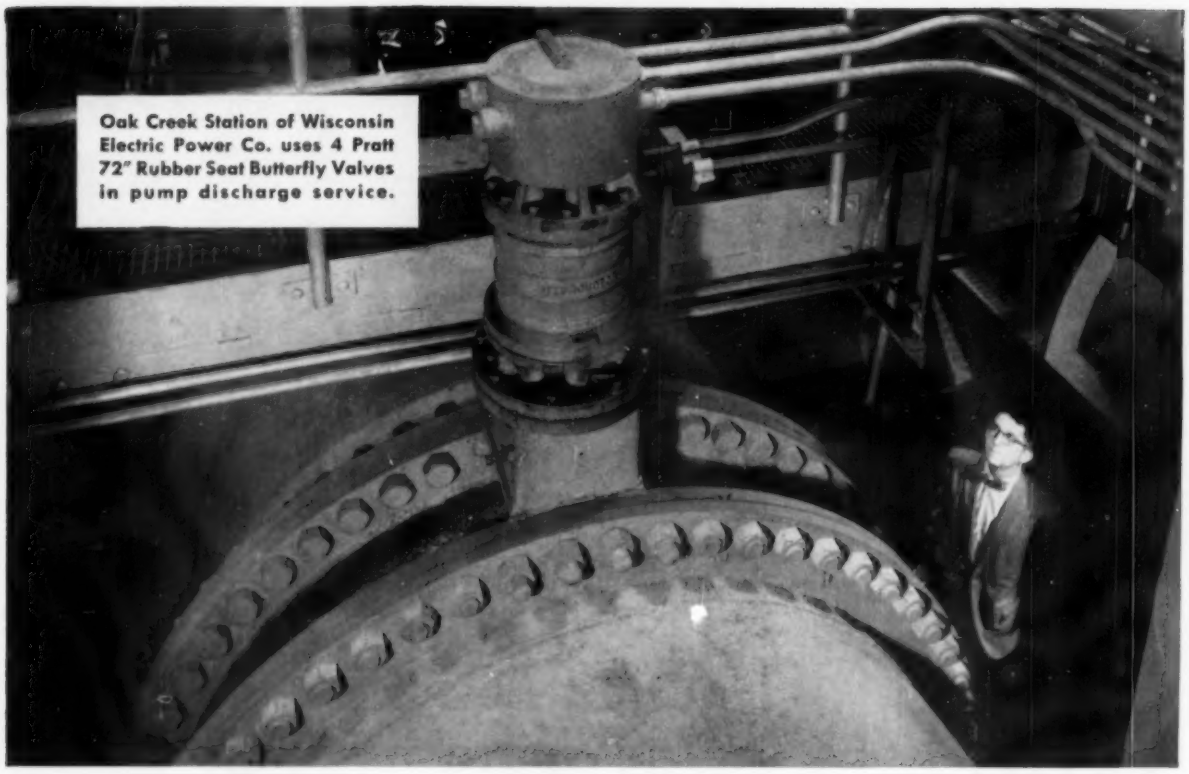
ENGINEERING

C-120

200 Madison Avenue, New York 16, N. Y.

SUPERHEATER LTD.

PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; SOIL PIPE



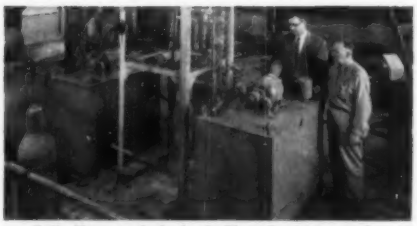
Oak Creek Station of Wisconsin Electric Power Co. uses 4 Pratt 72" Rubber Seat Butterfly Valves in pump discharge service.

MILWAUKEE...Pratt Butterfly Valves offer "two valves in one" for pump discharge

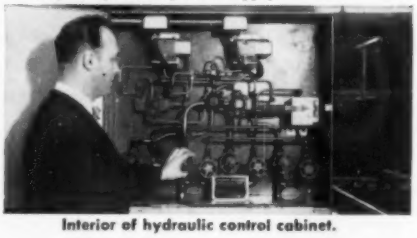
Pratt Rubber Seat Butterfly Valves in pump discharge service can be made to open and close in synchronization with pump operation, AND they close drop tight—combining, in a single valve, the functions normally achieved by separate shutoff and check valves. The simple combination of disc, shaft and efficient closure provides years of dependable performance without maintenance problems.

Pump discharge valves at Oak Creek Power Plant are hydraulically operated with oil motors. The electro-hydraulic system includes a bank of accumulators and complete auxiliary manual controls to permit operation under any emergency condition.

Pratt pioneered the use of rubber seat butterfly valves in power plants, and today offers the greatest aggregate experience on butterfly valving in the power field. For valve design—**with imagination**—see Henry Pratt.



Felix Kazmerchak, Ass't. Plant Engineer, and Ray F. Egebrecht, Pratt Representative, inspect hydraulic power supply.



Interior of hydraulic control cabinet.

Have you sent for your copy?...of Pratt's 40 page **Manual of Rubber Seat Butterfly Valves.** Useful—contains latest pressure drop and flow data, conversion tables, butterfly valve theory and application. CATALOG B-2D.

HENRY PRATT

RUBBER SEAT Butterfly Valves

Henry Pratt Company, 2222 S. Halsted St., Chicago 8, Ill. Representatives in principal cities

Get a better return on your investment...

Euclid TWIN-POWER

The use of Twin-Power in earthmoving equipment, developed and pioneered by Euclid, has enabled contractors, mines, quarries and industrial operations to make a far better return on their equipment investment. With two engines, each having a separate power train, bigger loads are moved faster and at lower cost . . . with only one operator.

Euclid's Twin-Power Scraper is a good example of this advanced engineering. With struck capacity of 24 cu. yds.—and 32 yds. heaped—this machine can work independently without the pusher tractor assistance required by conventional scrapers. All wheel drive, powered by two engines providing a total of 518 h. p through two Torqmatic Drives, gives this "Euc" unequalled work-ability. "Twins" have established new records for high production at low cost on a wide range of work.

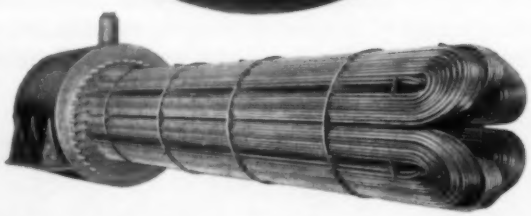
Twin-Power performance pays off in other Euclid equipment, too—crawler tractors and in rear-dump haulers of 40 and 50 ton payload capacities. If you use earthmoving equipment in your operations, Euclid Twin-Power may have an application that will produce a higher return on your investment. Complete information with technical assistance of an equipment specialist is available without obligation.

EUCLID DIVISION • GENERAL MOTORS CORPORATION • Cleveland 17, Ohio

Euclid Equipment

FOR MOVING EARTH, ROCK, COAL AND ORE

Highest Standard in Boiler and Pressure Tubing



Every length of Standard Boiler and Pressure Tubing is tested at pressures far beyond code requirements and can be readily bent or otherwise fabricated.

Electric welded boiler tubing is used today by all of the leading manufacturers of boilers and superheaters—stationary, marine, and locomotive—high or low pressure—and meets the requirements of government and commercial specifications.

With recent changes in the A.S.M.E. Boiler Code, it's now possible to use electric weld boiler tubing at pressures in excess of 2,000 lbs. High strength "Grade C" tubes are available for even higher pressures.

Uniformity of temper and wall thickness makes Standard tubes easier to roll for tight . . . sure fit. Standard's fine, smooth surface eliminates any need to polish ends for tight fit. Even a microscope won't spot the exact location of the weld.

Nowhere will you find any more modern and complete facilities for precision manufacture and inspection of Boiler and Pressure Tubing than you'll find at Standard.

For complete information on all Standard products and services send for free 8-page folder today.

Free 8-page folder on all Standard products. Write address below.

STANDARD

THE STANDARD TUBE COMPANY

24400 PLYMOUTH ROAD • DETROIT 39, MICHIGAN

Welded stainless tubing and pipe • Welded carbon steel mechanical • Boiler and Heat Exchanger • Exclusive rigidized patterns • Special Shapes • Steel Tubing – Sizes: ½" OD to 5½" OD – .028 to .260 wall • Stainless – Sizes: ¼" OD to 4½" OD – .020 to .165 wall.

The Yarway Impulse started a new era in steam trapping...

... it began in 1935, when Yarway applied a unique principle of thermodynamics to steam traps—and the Yarway IMPULSE Steam Trap was born.

Since then over 1,225,000 Yarway IMPULSE traps have proved themselves so well in service that today many other type traps are regarded as obsolete—an understandable reason why the Yarway IMPULSE type of steam trap is being imitated.

To industry, the Yarway IMPULSE trap makes possible a new high in thermal efficiency of equipment, a new low in trap operating maintenance ... resulting in increased production and higher profits.

THE THERMODYNAMIC PRINCIPLE

This is the principle on which the Yarway IMPULSE trap design is based—that variations in temperature of water discharging through two orifices in series cause variations in pressure in an intermediate chamber between the orifices, and that these changes in pressure may be utilized to open and close the trap valve.

ONE MOVING PART

There is only one moving part in a Yarway IMPULSE trap—a small, stainless steel valve. The entire valve assembly can be replaced in 5 or 6 minutes. It is the simplest of all steam traps to service.

EQUIPMENT HOTTER, SOONER—STAYS HOT

At "start up" the little valve opens wide to discharge air and condensate continuously. This brings equipment into production in the quickest possible time. The valve then actually floats on the condensate load, maintaining highest, steady temperatures.

A YARWAY IMPULSE STEAM TRAP TO MEET EACH TRAPPING REQUIREMENT

Research and development in the Yarway Steam Laboratory, plus intensive field testing, have produced a line of steam traps—*all* of the Yarway IMPULSE type . . . to efficiently meet each of the following classes of trapping service:

Normal requirements for pressures up to 600 psi call for Yarway Series 60 and 120 IMPULSE Traps in six sizes, ½" to 2".

Light loads for pressures up to 600 psi call for the ½" Yarway No. 20-A and No. 120-A IMPULSE Traps.

Heavy loads for pressures to 600 psi call for the extra high capacity Series 40 Yarway IMPULSE Trap, available in five sizes, ½" to 2½".

Highest pressure and marine requirements up to 2500 psi are met by the Yarway Integral-Strainer IMPULSE Trap, in six sizes, ½" to 2", flanged, screwed and socket weld types.

PLUS ADVANTAGES

- Small size and light weight
- Easy, low cost installation
- Minimum maintenance
- Non-freezing
- Stainless steel construction
- No adjustment of valve or seat needed for any pressure
- Low initial cost

NATIONALLY STOCKED, SOLD AND SERVICED

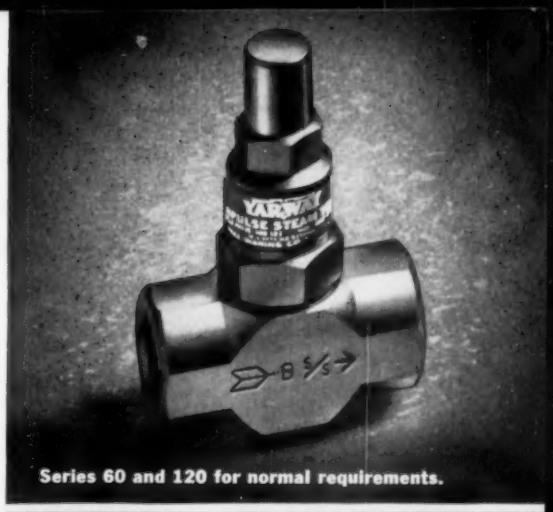
Over 270 Industrial Distributors stock and sell Yarway IMPULSE Steam Traps . . . and over 35 Yarway field engineers are available to help you select the right steam trap for the job.

Write for free, new bulletin "*The Why and How of Steam Trapping.*"

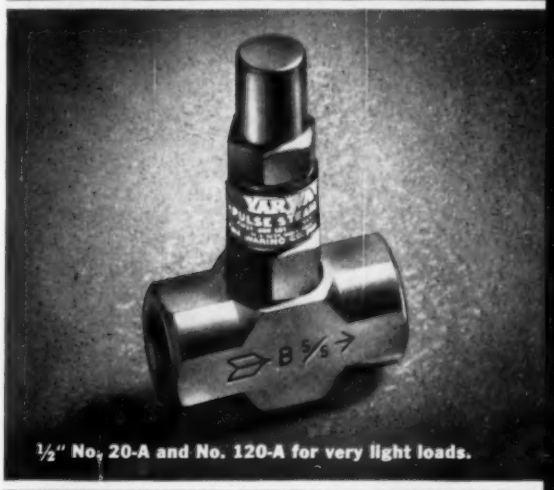
YARNALL-WARING COMPANY
100 Mermaid Avenue, Philadelphia 18, Pa.

YARWAY impulse®

...a good way to specify steam traps



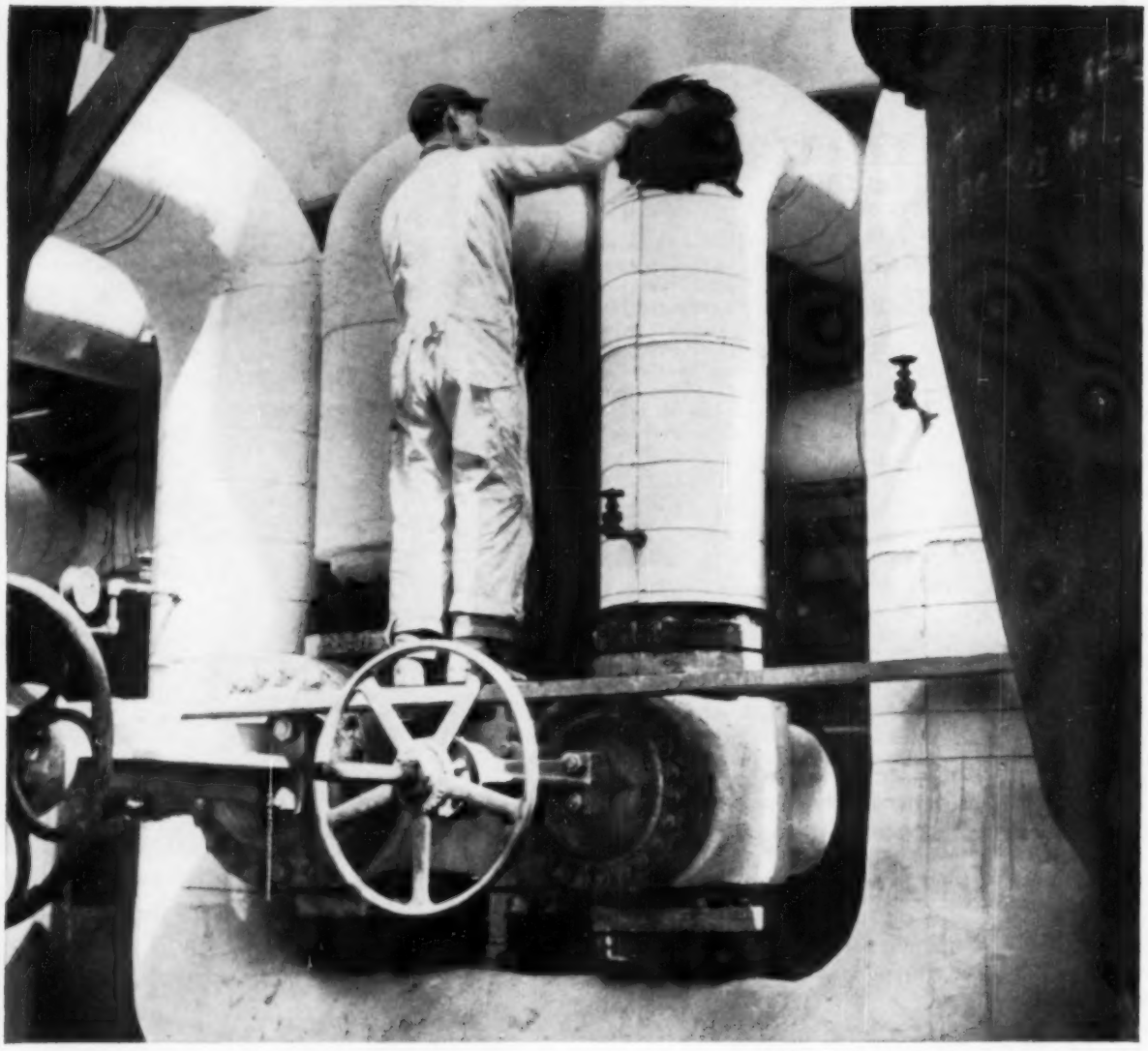
Series 60 and 120 for normal requirements.



½" No. 20-A and No. 120-A for very light loads.

Series 40 for very heavy loads.

Integral Strainer Impulse Traps for highest pressures and marine use.



J-M 85% Magnesia offers excellent workability . . . from application to finished coat.

Install lasting fuel savings and lower maintenance costs

. . . with J-M 85% Magnesia insulation!

At temperatures to 600F, no insulation is so widely used, or so closely associated with economy and increased operating efficiency as 85% Magnesia. Any wonder, then, that 71% of insulation maintenance engineers responding in a recent survey made 85% Magnesia their first choice in its temperature range.

There's good reason for this overwhelming acceptance. For J-M 85% Magnesia offers many practical advantages in both installation and service. Lightweight and readily workable, 85% Magnesia assures fast, easy application. In operation, it provides the ultimate in insulating value—long life—virtually no replacement—and the very minimum of maintenance.

To assure you maximum value in insulation application, Johns-Manville offers you complete planning and job-site service . . . practical recommendations by the world's most experienced insulation engineers, backed up by expert installation by J-M Insulation Contractors.

Write today for further information on Johns-Manville 85% Magnesia Insulation. Address Johns-Manville, Box 14, New York 16, N. Y. In Canada: 565 Lakeshore Road East, Port Credit, Ontario.

JOHNS-MANVILLE JM PRODUCTS

Johns-Manville INSULATIONS FOR LASTING THERMAL EFFICIENCY

MATERIALS • ENGINEERING • APPLICATION

ONE-SHOT "BOILER TREATMENT" GETS UNEXPECTED RESULTS

CEMENT MANUFACTURER SHOOTS THE WORKS!

CLEANING rotary cement-drying kilns by firing lead slugs into them to knock off accumulations inside is routine practice. The slugs go bounding and bouncing through the long drying kiln, doing a cleaning job equivalent to a whole crew of pick-and-shovel pilots. No one expects a slug to become so enthusiastic that it continues its chores inside the waste heat boiler attached to the far end of the kiln. In fact, the odds against getting a slug into the boiler *on purpose* are astronomical. But this one got there, odds and all, thus establishing a new type of one-shot boiler treatment which is hardly likely to become popular.

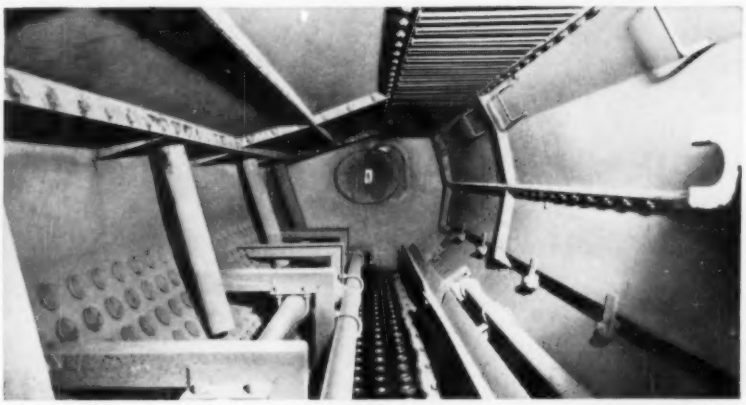
HOWEVER, *inside* the boilers at this large cement plant, Nalco System treatment helps make certain that boiler troubles, if any, are on the outside. Boiler feedwater is aerated, filtered, zeolite softened, evaporated and deaerated. A Nalco corrosion inhibitor is fed between deaerators and feed pumps for corrosion control throughout the steam and condensate return systems. Nalco catalyzed sodium sulfite does the oxygen scavenging on the discharge side of feed pumps. A Nalco internal treatment and caustic soda are fed directly into the boiler for pH control and scale prevention.

It is no wonder these boilers can turn out 169,000 lbs. of steam per hour, year after year, and stay like new—except, of course, for the wayward shotgun slug.

Nalco has not yet developed bullet proofing for boilers . . . But you can never tell what may come next! Meanwhile, we'll be happy to tell you more about effective Nalco Internal Treatment. Ask for Bulletin B1. National Aluminate Corporation, 6234 West 66th Place, Chicago 38, Illinois. In the Northwestern United States, Hawaii and Alaska: The Flox Company, Inc., Minneapolis, Minnesota. In Canada: Alchem Limited, Burlington, Ontario. Branches and affiliates in Spain, Germany and Italy.

THE TREATMENT: Lead slug, propelled by heavy powder charge in 8-gauge shell fired from a miniature cannon! "External treatment" with a vengeance.

THE RESULTS: "Plugged" boiler tube, pierced by lead slug on the pay off to one chance in a million. Internal treatment powerless here.



Steam drum in one of the Nalco-treated boilers at cement plant is typically clean and corrosion-free when opened for annual inspection.

Water treatment chemical mixing and proportioning room, where Nalco System treatment starts on its way to give complete steam system protection against scale and corrosion.

G-E looks

at coal as low-cost fuel

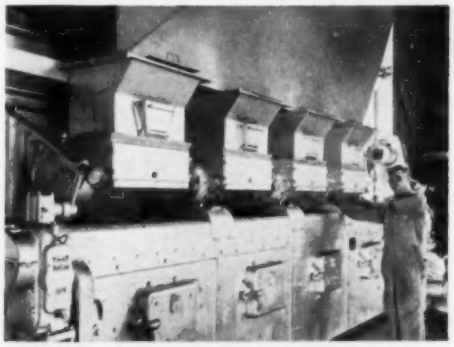
For low-cost steam generation and supply availability, GE burns coal in Louisville

General Electric's Major Appliance Division in Louisville, Ky., has six product manufacturing buildings, a warehouse and service buildings—5 million sq. ft. under roof. To generate all steam necessary for process work and heating requirements of this vast area, GE's power plant burns coal the modern way. Coal was chosen for availability and economy. A careful fuel cost study disclosed that, in the Louisville area, coal would give GE the lowest-cost steam generation of all fuels. In addition, full mechanization of GE's power plant has facilitated all details of coal handling and ash removal while completely overcoming the problem of air pollution.

Note cleanliness of firing aisle of GE's power plant. Steam generating equipment consists of five 150,000 lbs./hr. boilers—three by Henry Vogt Machine Co. and two by Riley Stoker Corp.

Facts you should know about coal

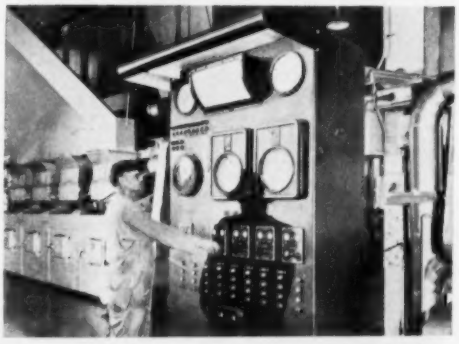
Not only is bituminous coal the lowest-cost fuel in most industrial areas, but up-to-date coal burning equipment can give you 10% to 40% more steam per dollar. Today's automatic equipment can pare labor costs and eliminate smoke problems. And vast coal reserves plus mechanized production methods mean a constantly plentiful supply of coal at a stable price.



Close-up of Detroit Rotograte Spreader Stoker on a Henry Vogt boiler. Riley boilers are fired by Riley Spreader Stokers. These stokers operate automatically, with continuous ash discharge. All boilers are equipped with non-segregating chutes.

Technical advisory service

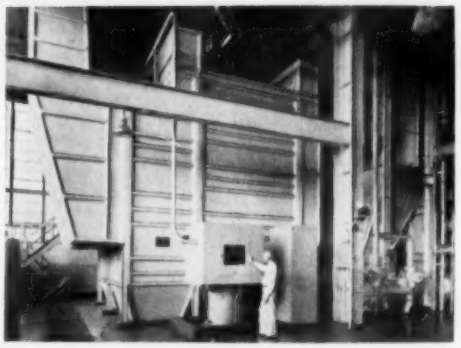
The Bituminous Coal Institute offers a free technical advisory service on industrial fuel problems. We welcome the opportunity to work with you, your consulting engineers and architects. If you are concerned with steam costs, write to the address below. Or send for our case history booklet, complete with data sheets. You'll find it informative.



Control panel for Boiler #5. These are Bailey Meter controls, air-operated, automatically handling coal feed, induced and forced draft, overfire air and feedwater regulation.

Consult an engineering firm

If you are remodeling or building new heating or power facilities, it will pay you to consult a qualified engineering firm. Such concerns—familiar with the latest in fuel costs and equipment—can effect great savings for you in efficiency and fuel economy over the years.

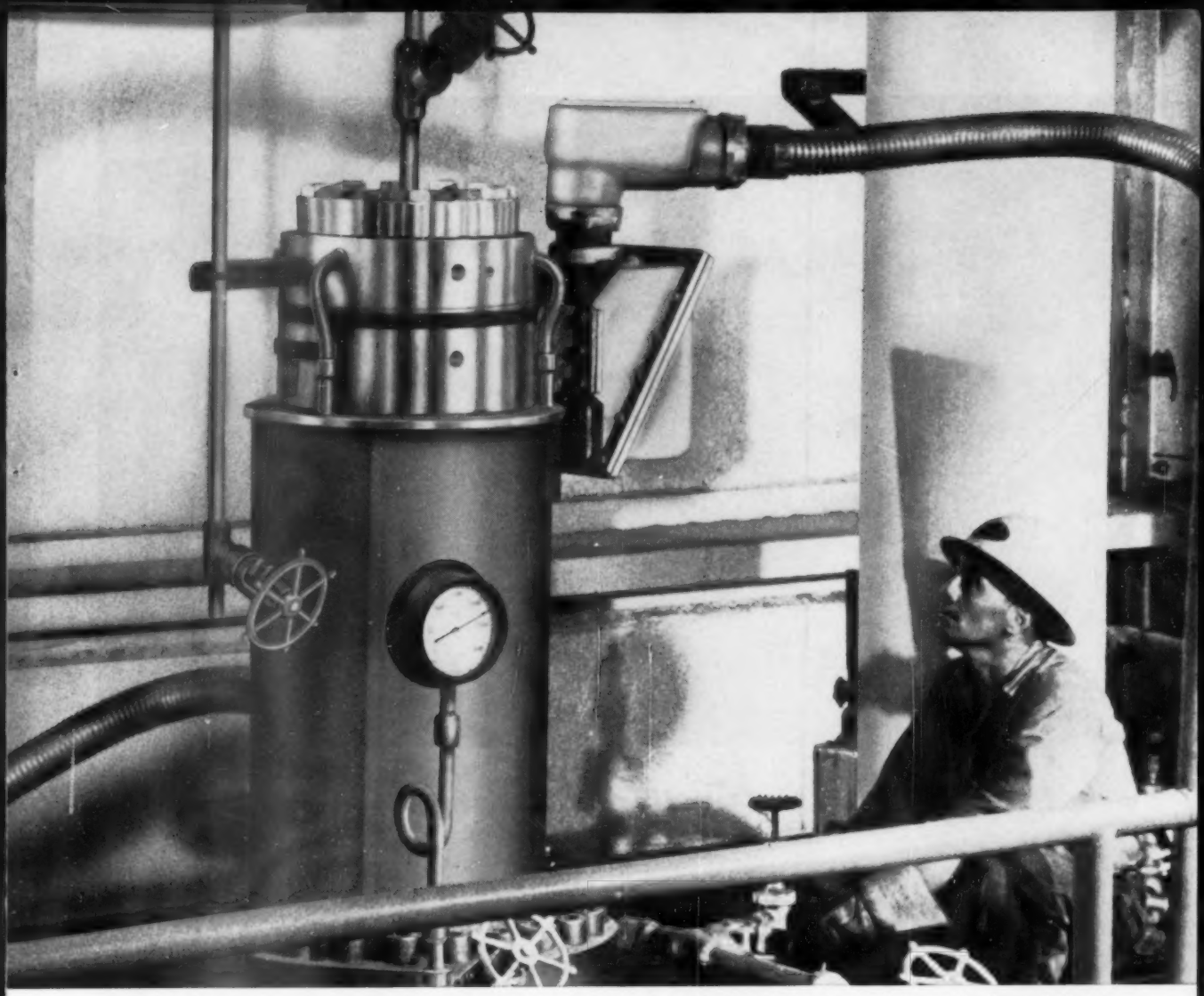


Prat-Daniel Electrostatic Precipitator and controls; at right, mechanical precipitator by American Air Filter Co. These are connected in series for automatic, efficient fly ash collection and disposal.

BITUMINOUS COAL INSTITUTE

Southern Building • Washington 5, D.C.

WHAT'S
SPECIAL
ABOUT
LJUNGSTROM'S®
easy maintenance features
Ljungstrom maintenance is fast and easy because it, too, is a "designed-in" function of the preheater. Necessary work has been foreseen by such money-saving features as:
• Self-cleaning action that loosens deposits by expansion and contraction—coupled with high-velocity soot blowers for daily in-operation purging.
• Cold-end heating elements are factory packed—can be easily replaced, or reversed when one edge starts to thin... which is vital for cold end service and essentially doubles surface life.
• Large inspection port and vapor-proof light to permit observation of heating surface, even during operation.
• Trained service engineers make periodic visits and are available on short notice for special problems.
That's why seven out of ten installations are Ljungstrom. For the full story write for our 38-page manual.
The Air Preheater Corporation, 60 EAST 42ND STREET, NEW YORK 17, N. Y.



One of three "canned" motor-pumps on the controlled circulation boiler in the 125,000-kw addition to the Seward Station.

PENELEC

uses Westinghouse "canned" motor-pumps

THE important factors of . . . reliability, insured by the "canned" motor armature and field . . . zero leakage in high-pressure applications . . . and the excellent experience reported by other users . . . led to the selection of Westinghouse "canned" motor-pumps in this installation.

When choosing the boiler equipment for an important new addition to electric power generating facilities, Pennsylvania Electric Company, Gilbert Associates, Inc., architect-engineers of the Seward Station, and Combustion Engineering, Inc., manufacturers of the controlled circulation boiler, selected Westinghouse pumps after evaluating the above all-important factors.

For information on these pumps and the benefits which can be helpful to you, contact your Westinghouse sales engineer, or write to the Westinghouse Electric Corporation, Atomic Equipment Department, Cheswick, Pa. J-57017R

YOU CAN BE SURE...IF IT'S

Westinghouse

Kellogg's Fabricating Abilities Keep Pace

Culminating many months of intensive work with Philadelphia Electric Company, including the testing and evaluation of numerous alloys, M. W. Kellogg is now fabricating the 2,400 ft. of main steam piping, which it will also install, for Eddystone Station Unit No. 1.

Piping is made of Type 316 Stainless, designed for use at 5,000 psi-1,200 F. at the turbine throttle. Calculated minimum wall equals 2.344 in. from Boiler to Sulzer Stop Valves (8 leads), 2.188 in. from Sulzer Stop Valves to Mixing Header (8 leads), and 2.656 in. from Mixing Header to Turbine (4 leads).

Kellogg's ability to handle the exacting task of bending, welding, heat treating, and testing such huge amounts of heavy-walled pipe to close schedules is a major reason for the company's long-standing reputation in the industry.

The M. W. Kellogg Company welcomes the opportunity to discuss its complete power piping design, fabrication, and installation facilities with consulting engineers, engineers of power generating companies, and manufacturers of boilers, turbines, and allied equipment.

M. W. Kellogg has developed many welding techniques for the fabrication of high alloy steam piping, including K-Weld*. With this unique technique of arc welding, the pipe interior is under controlled inert gas pressure —assuring complete root bead penetration and a highly uniform internal contour without the use of backing rings.

FABRICATED PRODUCTS DIVISION

THE M. W. KELLOGG COMPANY, 711 THIRD AVENUE, NEW YORK 17, N. Y.

A SUBSIDIARY OF PULLMAN INCORPORATED

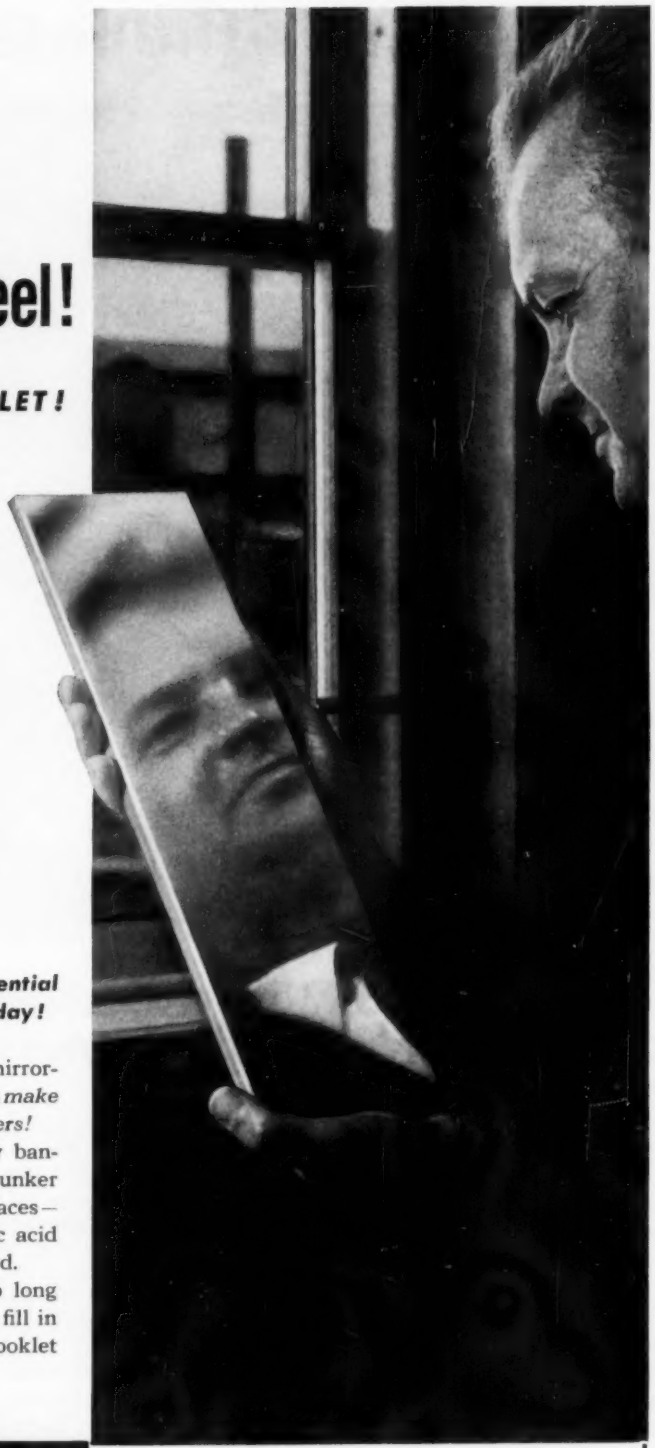
The Canadian Kellogg Company Ltd., Toronto • Kellogg International Corp., London • Kellogg Pan American Corp., New York • Societe Kellogg, Paris • Companhia Kellogg Brasileira, Rio de Janeiro • Compania Kellogg de Venezuela, Caracas

POWER PIPING—THE VITAL LINK

**Trademark of The M. W. Kellogg Company*

LOOK NOW
into Lukens clad steel!

GET THIS INFORMATIVE BOOKLET!



See for yourself how clad steel provides potential savings of $35,000! Send for your copy today!

In 16 figure- and fact-filled pages, it shows how mirror-smooth, corrosion-resistant stainless-clad steel can *make your coal handling equipment outlast your boilers!*

It tells you why stainless-clad steel virtually banishes coal hang-ups in your hoppers, chutes, bunker noses, pipes, spreaders. Prevents corroded surfaces—and resulting abrasive wear—caused by sulfuric acid in wet coal. Is easy to fabricate. Readily modified.

One short minute now can point the way to long years of economical coal handling—if you'll just fill in and mail the coupon. You'll get this important booklet at once. Lukens Steel Company, Coatesville, Pa.

Helping industry choose steels that fit the job

LUKENS ®

Manager, Marketing Service
LUKENS STEEL COMPANY
941 Lukens Building, Coatesville, Pa.
Please send me a free copy of your 16-page booklet, "Stainless-Clad Steel for Coal Handling."

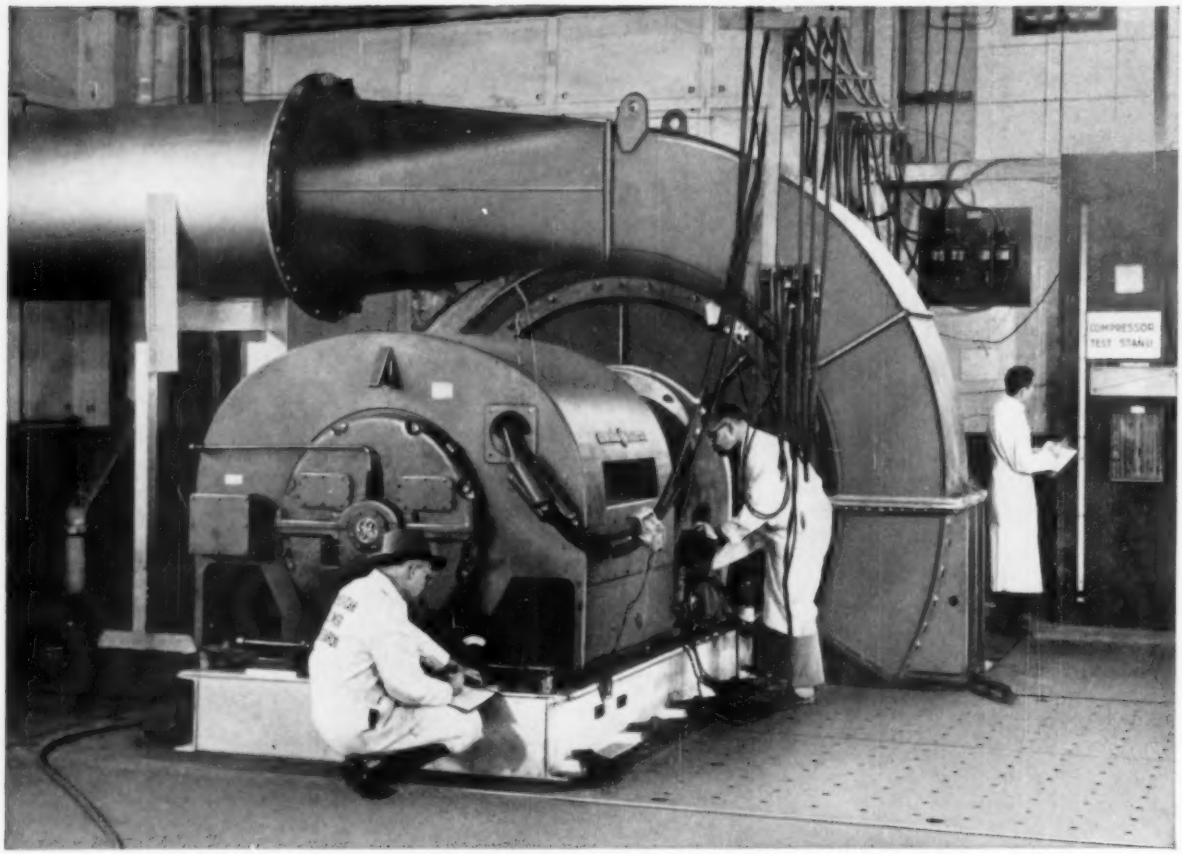
Name _____

Title _____ *Company* _____

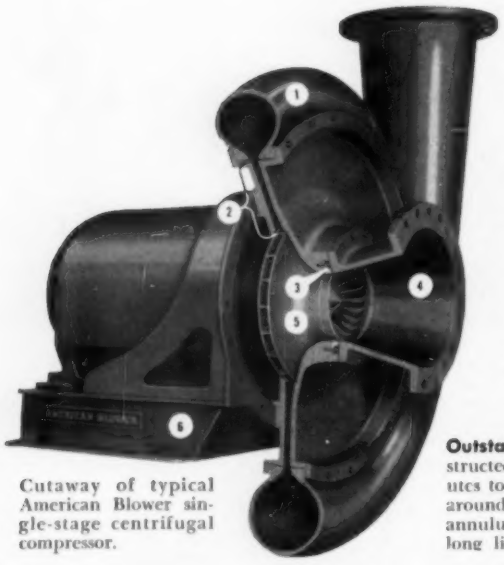
Street Address _____

City _____ *Zone* _____ *State* _____

Here's the latest air-handling



LABORATORY TESTED CENTRIFUGAL COMPRESSOR DELIVERS 330,805 POUNDS OF AIR PER HOUR!



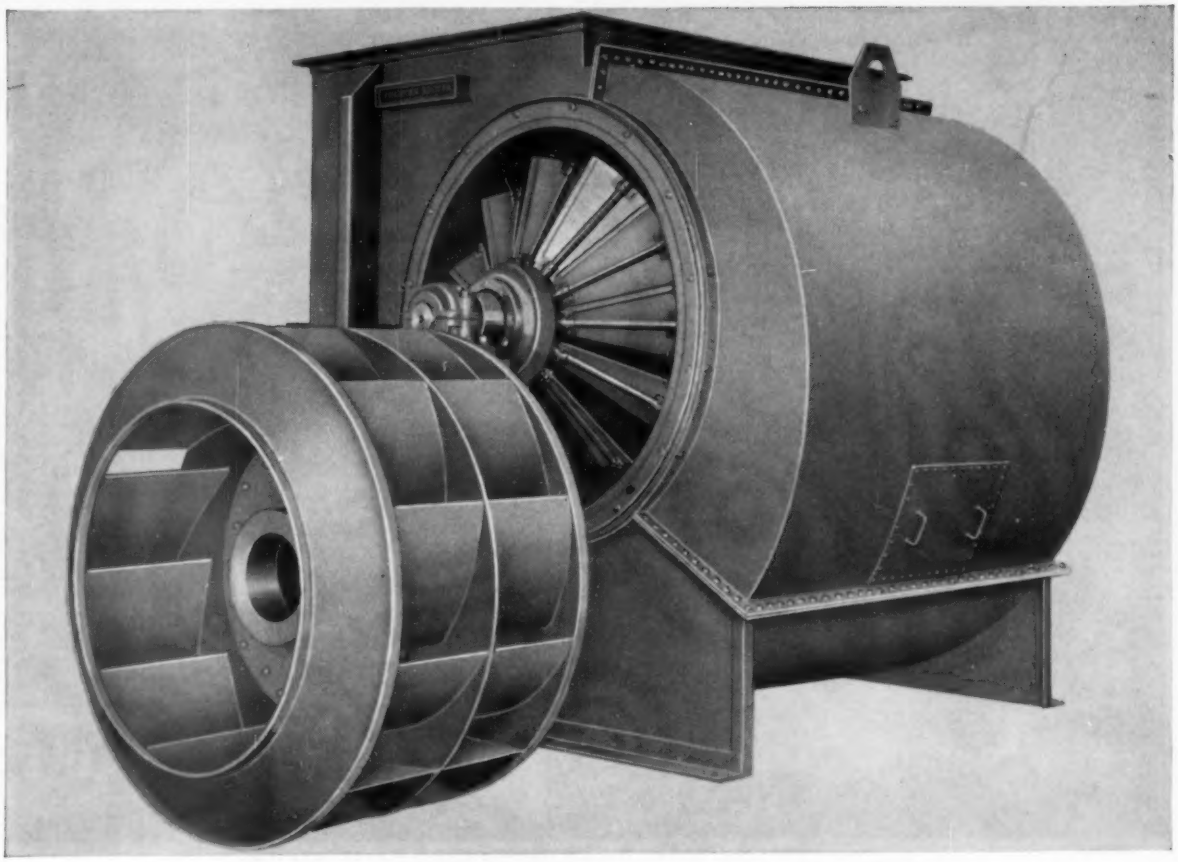
Cutaway of typical American Blower single-stage centrifugal compressor.

With the trend toward higher pressure requirements, American Blower has designed and built centrifugal compressors to furnish air for cyclone fired boilers. These compressors incorporate the use of a horizontally split, welded steel volute casing, variable inlet guide vanes, welded steel impeller of the shrouded type with impeller shaft supported by two journal bearings plus a Kingsbury thrust bearing arranged for positive forced-feed lubrication. This highly efficient compressor is driven by a 1000 HP, 1800 rpm, induction motor, delivers 330,805 pounds of air per hour at a static discharge pressure of 67.5 inches water gauge.

Like every American Blower single-stage centrifugal compressor – 30 to 2250 HP – this compressor has been completely tested in accordance with the A.S.M.E. Power Test Code. Such testing guarantees the mechanical operation and performance of all American Blower compressors.

Outstanding features: (1) Improved scroll-shaped casing design. (2) Unobstructed long diffuser passage converts velocity energy into pressure, contributes to quiet operation. (3) Annulus packing minimizes recirculation of gas around impeller inlet. (4) Removable inlet nozzle for accurate alignment of annulus packing. (5) Aero-dynamic design of impeller blades for high efficiency, long life. (6) Welded-steel baseplate "stress relieved" prior to machining.

equipment from American Blower

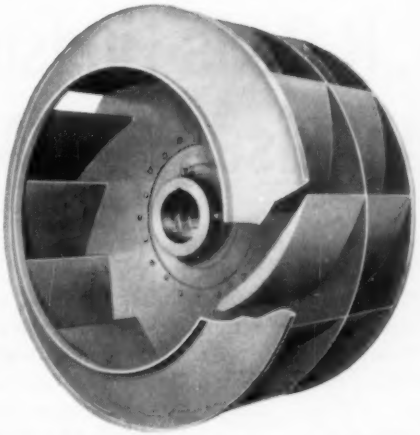


AIRFOIL FAN HAS ADVANCED DESIGN FOR HIGH EFFICIENCY, LOW OPERATING COST

Featuring a functionally designed airfoil blade, American Blower's improved Airfoil Fan is the industry's best in the non-overloading-horsepower type of centrifugal fan.

That's because smooth interworking of improved streamline inlets, wheel rims, and housing minimizes turbulence, resulting in higher efficiency, lower power consumption. The non-overloading-horsepower characteristic makes it possible to select a driving motor close to the fan horsepower.

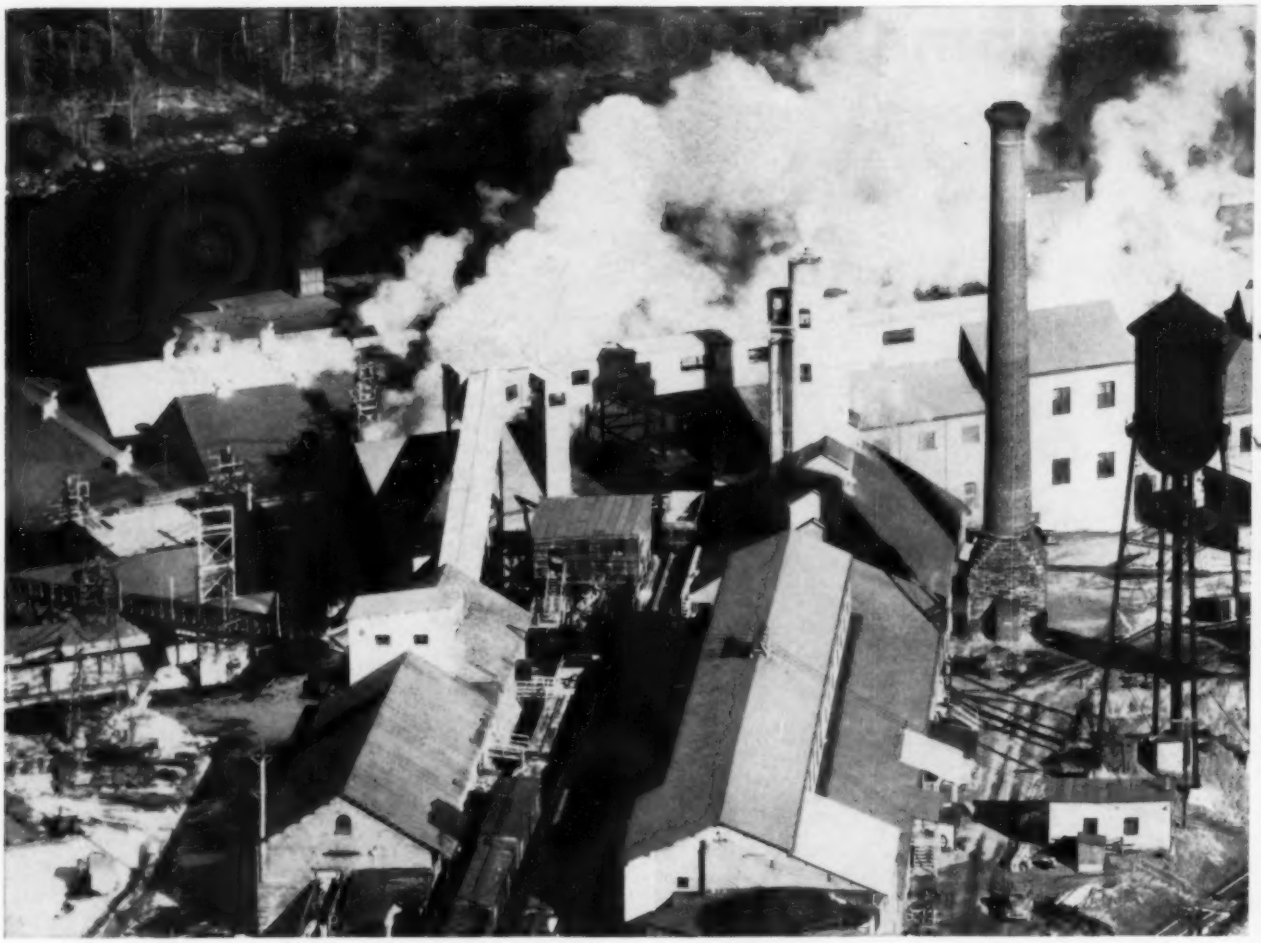
Why not talk to an American Blower sales engineer about *your* requirements. His knowledge of air-handling applications can prove invaluable to you. Call our nearest branch office, or write: American Blower Division of American-Standard, Detroit 32, Michigan. In Canada: Canadian Sirocco products.



Special design of the airfoil blade and matching streamline inlet are the top features of American Blower Airfoil Fan. The dieformed, reinforced, and welded blades are extra strong, extremely efficient. Single- and double-inlet Airfoil Fans are available in many sizes, and for volumes up to 1,000,000 cfm.

AMERICAN BLOWER

Division of AMERICAN-Standard



Aerial view of the International Paper Company plant at Corinth, New York

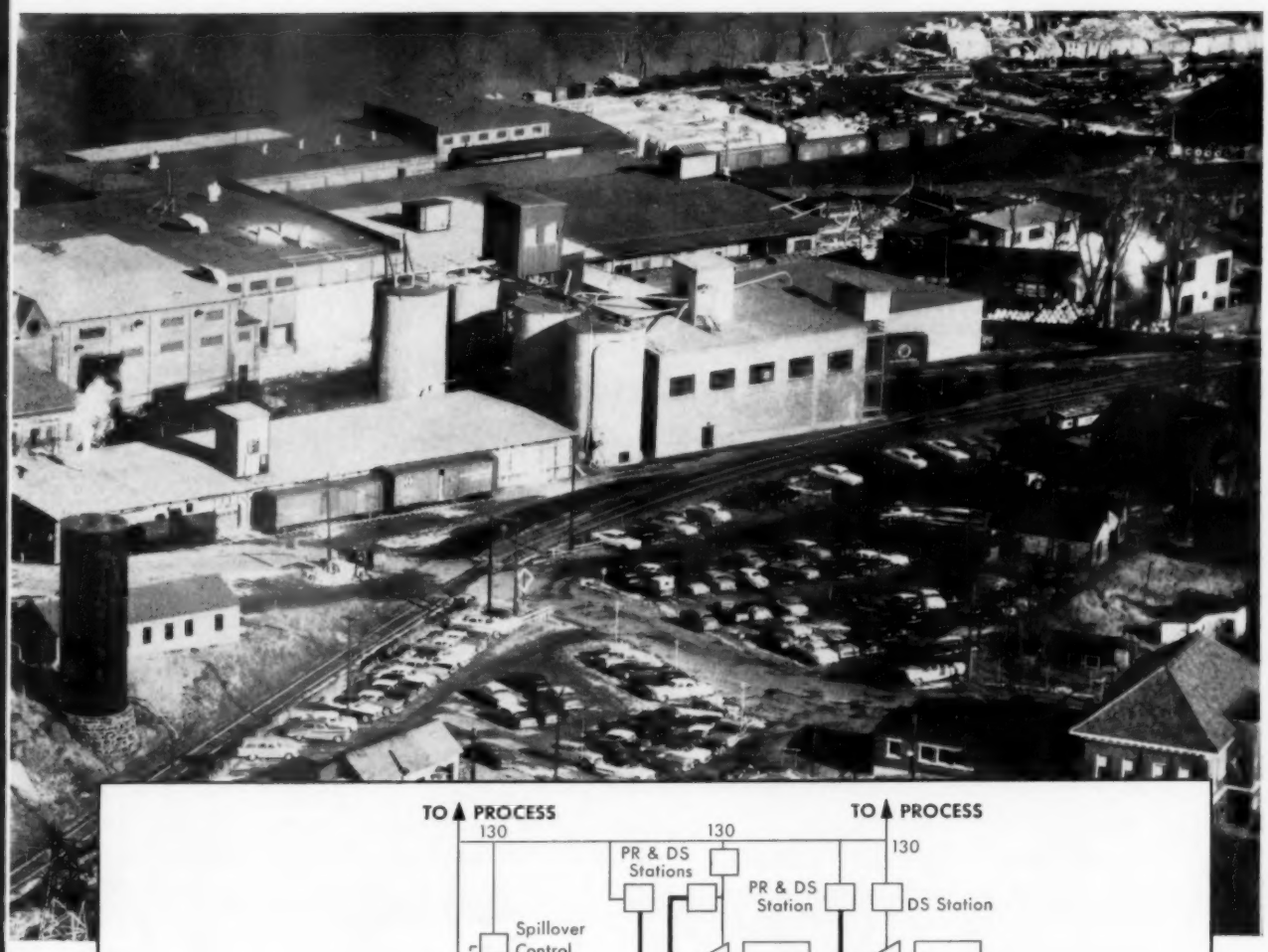
Need help with steam plant expansions? I. P. Co.'s Hudson River Mill has used HAGAN...since 1936

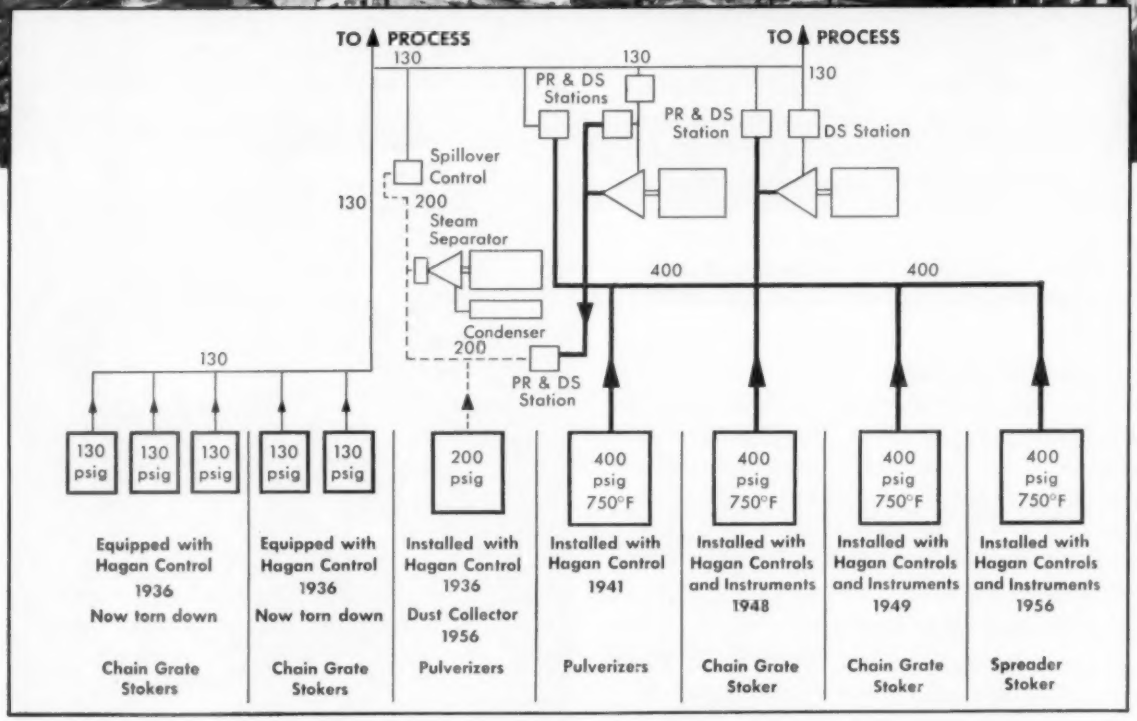
In 1936, the International Paper Company plant at Corinth, New York, decided to install automatic controls on the five boilers then in service (see chronological diagram at right). A Hagan system was chosen for the first three boilers to be converted. Subsequently the remaining two boilers were also put on Hagan automatic combustion control.

Since then, as plant expansions presented new problems of boiler operation and steam distribution, Hagan combustion controls, pressure reducing and desuperheating stations, spillover controls and other systems were added.

Hagan equipment is also used for steam separation, paper machine drying control, water temperature control and chemical feeding systems. In 1956, a Hagan Dust Collector was installed on Boiler No. 7 to control fly ash in the shipping area. Hagan is proud of so long a record of continuous service, and of the results that have been achieved.

Hagan engineers have more than 37 years of experience in the application of accurate, dependable Hagan equipment to combustion control problems of all kinds. Why not put this experience to work on your control problems.





HAGAN CHEMICALS & CONTROLS, INC.

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Eastern Public Utility Installs Two More Koppers Electrostatic Precipitators to Remove Fly Ash

Major Utility has installed 8 Koppers Electrostatic Precipitators since 1947

YEARS of cost-saving, highly efficient performance preceded this latest installation of Koppers Electrostatic Precipitators. During these years, this leading Eastern public utility was able to judge Koppers by on-the-job operation—the most positive proof of performance.

Proves Performance on the Job

Ten years ago, this company purchased its first two Koppers Electrostatic Precipitators for fly ash removal. Satisfactory performance and low maintenance costs justified the purchase of additional Koppers units that were installed in a total of 4 stations. The eight units furnish highly effective, trouble-free operation in a varying range of CFM capacities.

Supplies a Wide Range

The eight Koppers Electrostatic Precipitators serve boilers ranging in capacity from 570,000 #/hr to 950,000 #/hr. Guaranteed efficiency runs as high as 98%, depending on the need of each application. This ability to engineer for a wide range of capacities enables Koppers to satisfy the needs of each station.

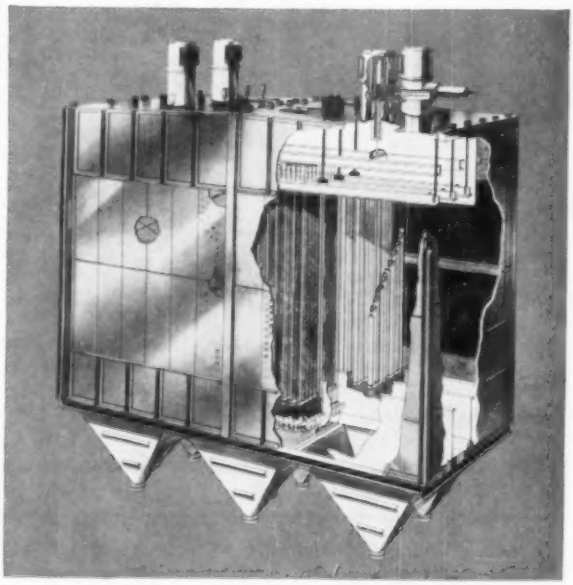
Meets Individual Plant Needs

Koppers custom-designs each Electrostatic Precipitator. Koppers units remove boiler fly ash before the flue gas is discharged from the stack. In designing Electrostatic Precipitators, Koppers utilizes its knowledge of the characteristics of various coals, types of boilers and methods of firing.

Backed by Know-How

Koppers gas cleaning experience goes back 75 years. This experience is backed up by extensive research facilities at Verona, Pa., and Baltimore, Md. From this experience and research has come gas cleaning equipment for all sizes and types of plants.

Get the most out of your gas cleaning dollar. Write KOPPERS COMPANY, INC., Metal Products Division, Industrial Gas Cleaning Dept., 4411 Scott Street, Baltimore 3, Maryland.



This cutaway photo of a Koppers Electrostatic Precipitator shows shell, vibrators, and collecting and discharge electrodes. The actual design and arrangement of elements vary widely because Koppers Electrostatic Precipitators are custom-engineered to fit the requirements of each installation.

Coal-Handling Tractor Shovel HAS BIG BUCKET . . . WILL TRAVEL

Will travel . . . there's the key to the extra value of an Allis-Chalmers HD-11G tractor shovel with 3¾-yd coal bucket. Its combination of capacity and mobility may be utilized in many ways.

TRAVELS ON THE STOCKPILE Long crawler tracks give it the stability to work right up on the storage pile . . . enables it to spread coal in horizontal layers. This eliminates the formation of flues — the main cause of spontaneous combustion.

TRAVELS ABOUT THE YARD The HD-11G builds stockpiles with equal ease anywhere in the yard. There is no need to limit storage piles to areas served by fixed structures.

TRAVELS FROM JOB TO JOB There need be no idle time for an HD-11G for it is also an expert at countless additional jobs. It can remove and load cinders, help on plant road maintenance, clear and load snow . . . handle many other yard maintenance jobs.

Let your Allis-Chalmers construction machinery dealer show you how the HD-11G can bring new efficiency to your coal-handling operation — and also eliminate the need for specialized machines. Ask to see the three other tractor shovel models, with coal buckets ranging from 2¼ to 7 cu yd. Allis-Chalmers, Construction Machinery Division, Milwaukee 1, Wisconsin.

ALLIS-CHALMERS *Engineering in Action*

. . . ANSWERING YOUR QUESTIONS ABOUT

Apexior Number 1 for boilers

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HOW MUCH CLEANING IS NECESSARY BEFORE APEXIOR-COATING?

A surface no cleaner than good operating practice demands is all the foundation needed for Apexior Number 1 — the coating that ever after holds steel at newly cleaned efficiency.

HOW DOES THE DAMPNEY TEST KIT SERVE?

By saving man-hours that might be expended needlessly. A quick, three-step check tells when cleaning has delivered just-right surfaces, prepared neither less nor more than necessary.

DOES THE APEXIOR-COATED BOILER STAY CLEAN IN SERVICE?

Because Apexior discourages deposit formation and bonding, the coated boiler needs less cleaning, less often. Inspection is easier, too — for a sound Apexior surface reveals itself readily, assuring equally sound steel 2½ mils beneath.

DOES CHEMICAL CLEANING AFFECT APEXIOR?

In no way. Rather, Apexior takes on the added function of preventing acid-metal contact and the resultant attack, however slight, that might occur. Those engaged in chemical cleaning report that Apexior speeds the process by keeping deposits few and less tenacious.

WHEN SHOULD A BOILER BE APEXIOR-COATED?

To seal water-contact surfaces permanently at highest efficiency and take them safely through the initial shake-down period, a new boiler should be Apexior-coated immediately after erection; an operated boiler, immediately after cleaning.

IS APEXIOR BOILER COATING DIFFICULT?

Not at all. Apexior is brush applied — by hand to drums and flat areas; by air-driven tube turbine, brush-equipped, to tube interiors. Application is regularly made by plant crews with or without initial Dampney supervision.

HOW LONG DOES APEXIOR LAST?

A conservative estimate: Five years before retouching or renewal. Under ideal conditions: Ten to twelve . . . for Apexior's primary function is preventive maintenance — its life, directly proportional to the work it has to do in supplementing good boiler practice.

This message — one of a series — presents more reasons why Apexior Number 1, first used inside boilers in 1906, is today manufactured in the United States and four foreign countries to meet world-wide demand for protection of

- *boiler tubes and drums*
- *evaporators*
- *deaerating and feedwater heaters*
- *steam turbines*

MAINTENANCE FOR METAL

THE DAMPNEY COMPANY

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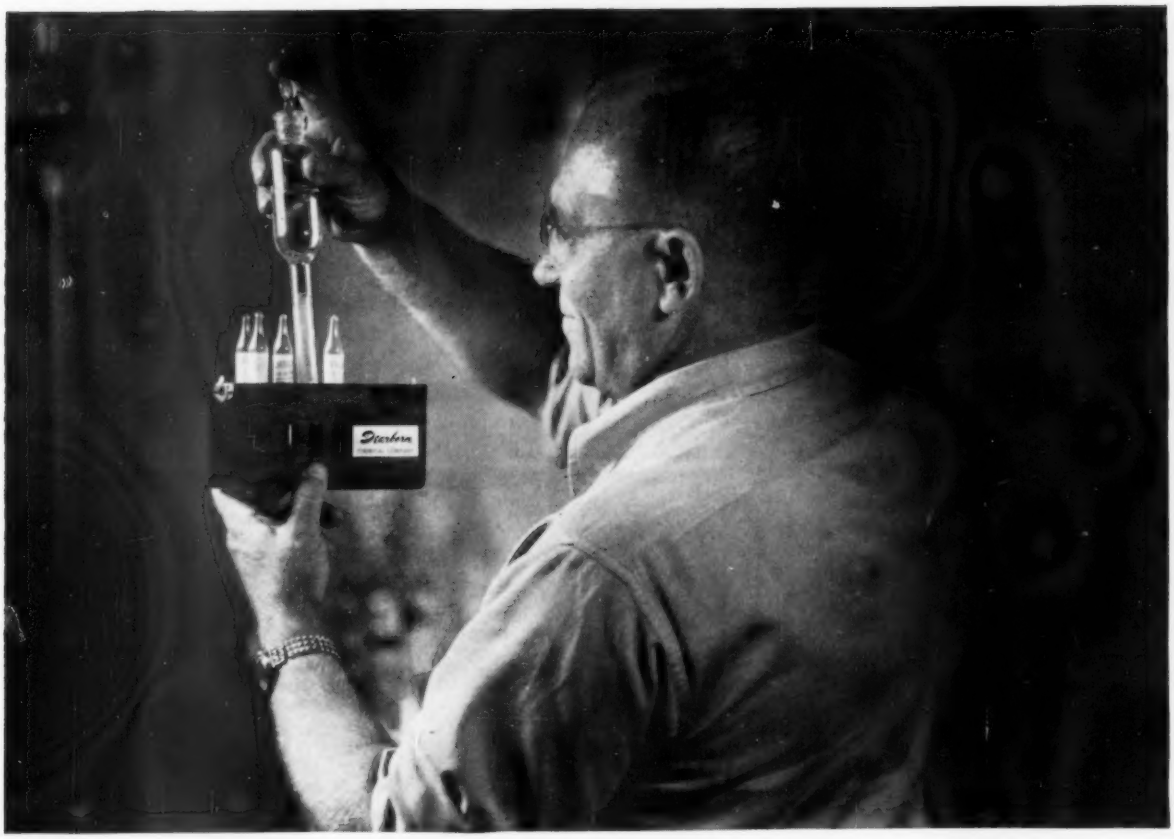

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With this easy-to-use kit you completely eliminate guesswork on dosages to assure positive corrosion control of the entire system at lowest possible treatment costs.

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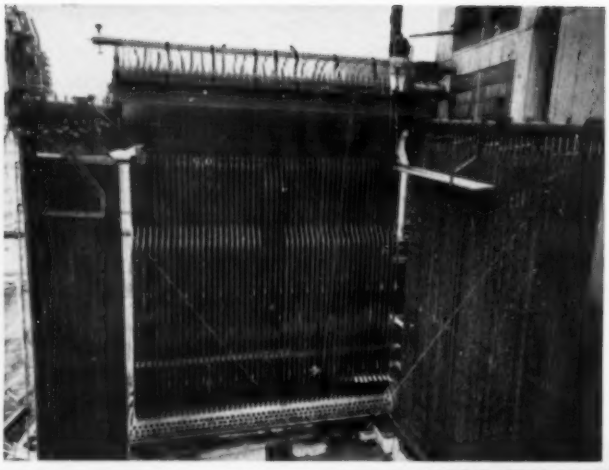
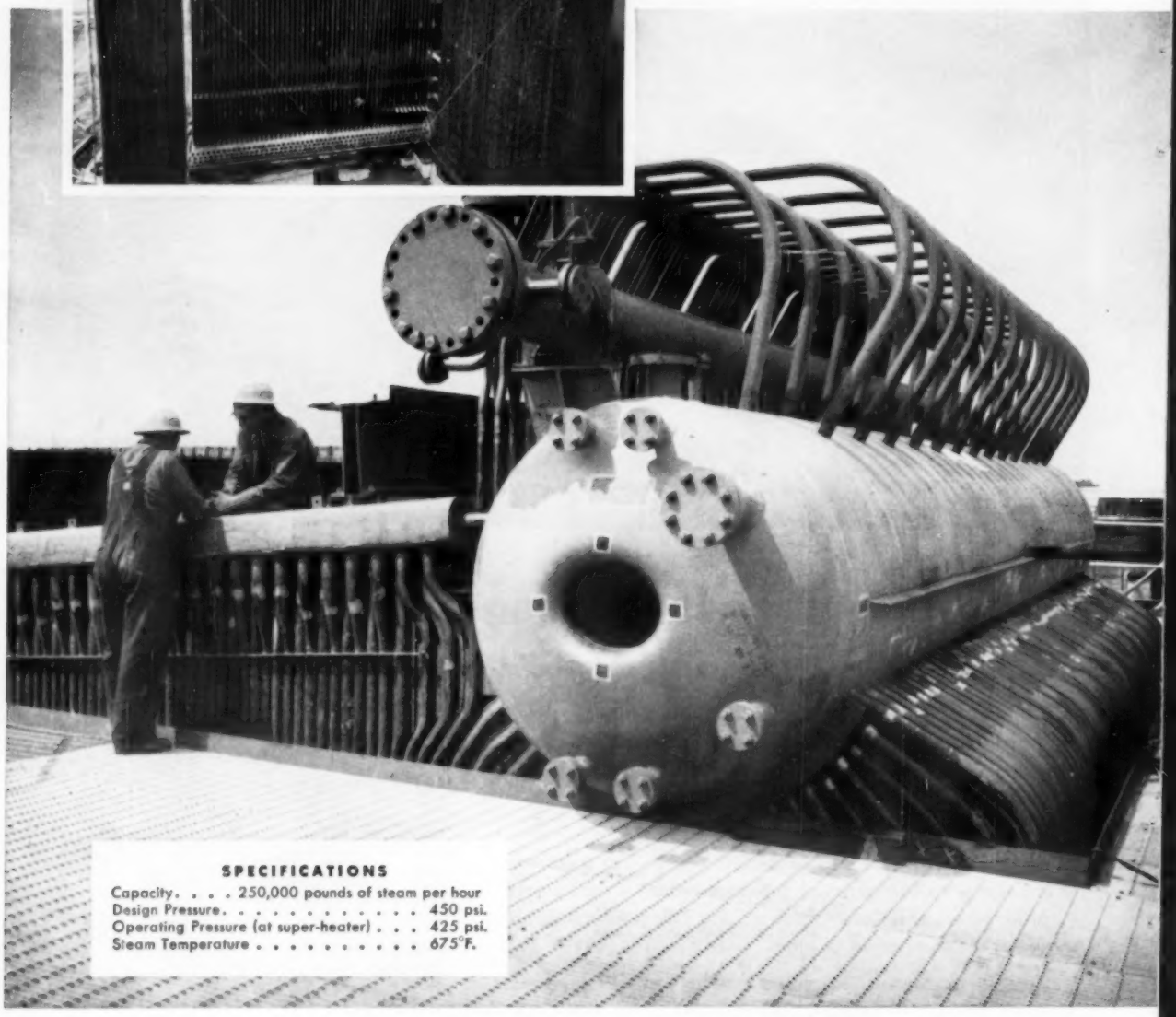


Republic



SPECIFICATIONS

Capacity	250,000 pounds of steam per hour
Design Pressure	450 psi.
Operating Pressure (at super-heater)	425 psi.
Steam Temperature	675°F.

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speed installation, assure top performance

"In Service on Time"! That is the target of Combustion Engineering, Inc., general boiler designers and erectors now working on the construction of a new boiler installation for the Magnolia Petroleum Company at Beaumont, Texas.

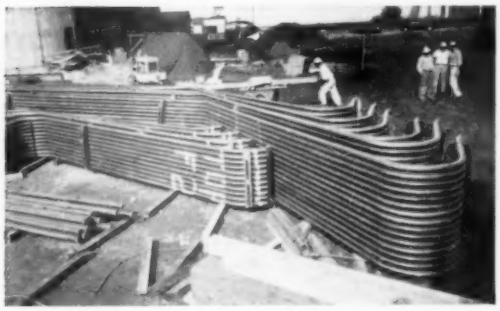
And past performance-records indicate Combustion Engineering will make this target, too, aided by the reliability, dependability, workability of Republic ELECTRUNITE® Boiler Tubes.

This Magnolia Petroleum Company installation has a design pressure of 450 psi., operating at 425 psi. at superheater outlet with a total temperature of 675°F., 250,000 pounds of steam per hour. Republic ELECTRUNITE meets every job requirement.

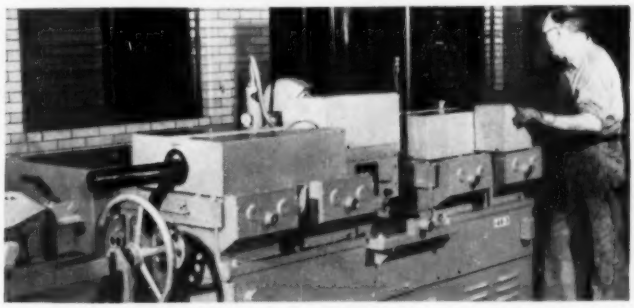
Each length of Republic ELECTRUNITE Boiler Tubing is hydrostatically or electronically tested to conform to the applicable ASTM specifications and the requirements of the ASME Boiler and Pressure Vessel Code, as well as local, state, and boiler-insurance requirements. In addition, Republic ELECTRUNITE is approved on an equal basis with tubes made by any other process up to 850°F. It is available for pressures over 2000 psi. in various sizes and wall thicknesses.

That is why more and more Republic ELECTRUNITE Boiler Tubing is specified by designers, engineers, and erectors for vital steam generating units operating in every industry and community field.

Your local Republic representative will be happy to supply you with all the facts on Republic ELECTRUNITE Boiler, Condenser and Heat Exchanger Tubing. Call today, or send coupon for literature.



Uniform ductility of Republic ELECTRUNITE Tubing makes bending to a precise contour easy. These units have been tack welded, shipped, are ready for final installation. Saves time in handling, transportation and erection.



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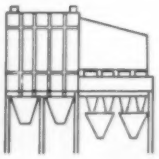

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Editorial

Making Meetings Manageable

The task of following technical developments in the power field requires attendance at a number of meetings throughout the year. Over a period of time a certain critical awareness of the conduct of these various meetings develops. More often than not the program chairman merits a pat on the back. Once in a while, however, a situation develops that needs corrective action. This past month we encountered what we consider a programming error on three widely separated occasions.

Our first encounter was at the newly organized Power Conference of the ASME's Power Division in Allentown, Pa., October 21–23. This Conference featured one full afternoon session on the design problems of the once-through subcritical pressure Portland Station of the Metropolitan Edison Co. The individual papers were good, the discussion pertinent but the session was overly long. Then in Pittsburgh at the Eighteenth Annual Water Conference of the Engineers Society of Western Pennsylvania the same difficulty arose. Here a panel on surface condenser tubes was presented and nine papers were read. Again, too long. Lastly at the Atomic Industrial Forum Meeting in New York City, October 28–30, the U.S. power reactor program was reviewed, entailing some *fourteen* separate reports for one single session!

The reasoning behind such scheduling is the understandable desire of the program chairman to make his session comprehensive as well as authoritative. Unfortunately it is unfair to both speaker and audience to have a session become a test of physical endurance. What then is the solution?

The British have long advocated the use of a reporter for such single-subject sessions. The reporter's function is to review all the proposed papers before the session and then make a report at the meeting. His report is drawn from the major points of the individual papers with special attention to the differences and the agreements between the views of the individual speakers. Further, prepared discussions of the papers are then read and finally the authors present their own closure commenting as they may on discusser, reporter, or other speaker. We have seen this method attempted but once—at the International Combustion Conference at M.I.T. in June of 1955. In our opinion this is too good a solution for the cumbersome session not to be tried more often here in the U.S.A.

An Asset or a Burden?

Speaking before the Atomic Industrial Forum on October 29 in New York City, J. K. Busby, executive vice president of Pennsylvania Power & Light Company, asked this question. Is nuclear power going to be a cost-burden factor or a cost-relieving factor in the American economy?

The long term prospect of higher fuel costs is inescapable, and that means nuclear power must assume increasing importance in the future. For the short term, however, what concerns Mr. Busby and many other utility executives is the sizable disparity in cost between nuclear and conventional power. Under present economic conditions *widespread* generation of power from nuclear sources would place an unnecessary burden upon the American consumer of electricity. Mr. Busby, citing his own company's participation in the Pennsylvania Advanced Reactor Project, stressed the role of the utility companies in footing the bill for development costs of the nuclear industry.

But this may have to be supplemented, as Charles H. Weaver, vice president of Westinghouse Electric Corporation, pointed out at the same meeting. In his words, "Practically all of our large utilities have identified themselves in some manner with the nuclear development program. I am sure that the far-sighted development contribution of our large utilities will continue. I hope that it will increase. But it would appear that the demonstrated performance of full scale atomic plants must precede any sweeping investment of private capital in this new energy source. I do not see how this can come about in less than ten years. . . . It appears that we do not require and cannot justify the number of large nuclear plants in this country over the next decade which may be felt necessary to meet our developmental goals. I suggest that such reactors can just as well be built abroad where the need is more urgent. But to accomplish this, Government must recognize the limitations of American industry and support it in a more positive and thorough manner than in the past."

Perhaps this is the answer to the problem of maintaining American leadership in the atomic field. A crash program to build large domestic nuclear stations in order to keep up with the Joneses overseas would clearly be a burden on the American electric consumer. A government-industry partnership that would permit American participation in European and Japanese projects where the energy requirements are more urgent and fuel is more costly might provide the essential nuclear operating experience. In engineering terms, under technical assistance agreements, it really makes little difference where the operating experience is gained. And the end result may be a sounder American atomic industry that is capable of meeting the needs of the utility industry when nuclear power generation becomes economically competitive in this country.

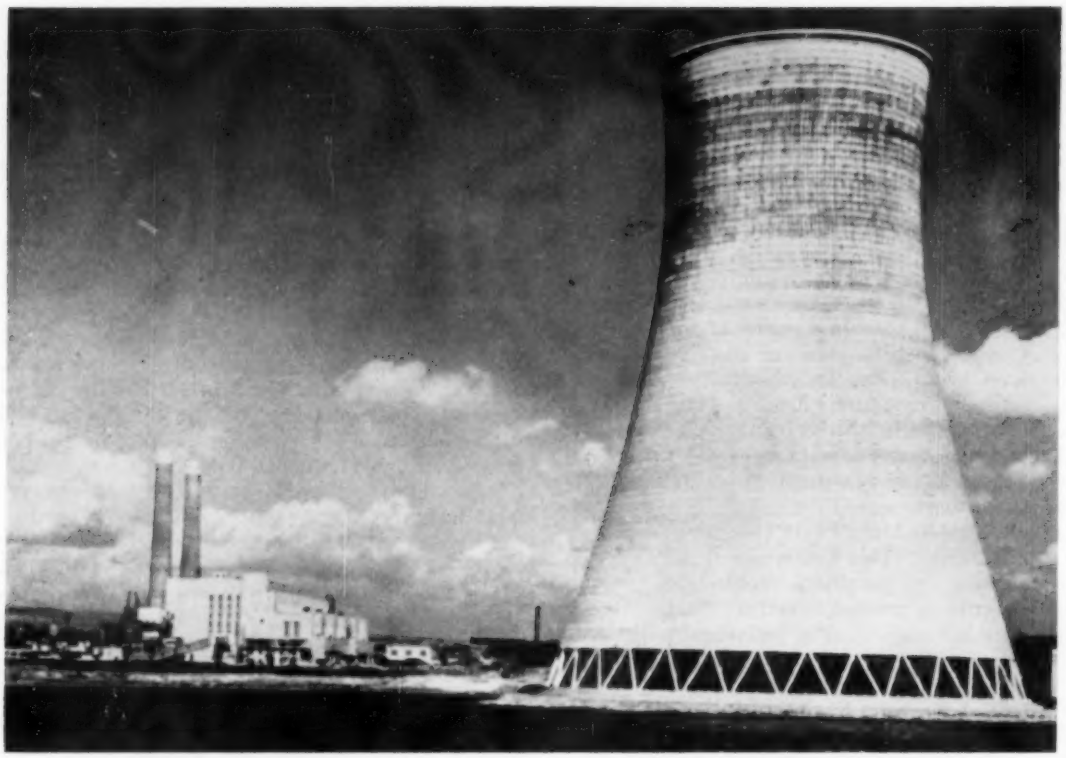

Fig. 3—Hyperbolic natural draft cooling tower for 60,000 gpm capacity (Courtesy of Central Electricity Authority.)

Selection and Application of Cooling Towers

By E. E. GOITEIN†

Foster Wheeler Corp.

As the availability of natural sources of large quantities of circulating water is diminishing rapidly, cooling towers are growing in importance to most steam-electric utilities. This paper is intended especially to assist those who, for the first time, are finding it necessary to employ this equipment. General considerations, guides, and examples are given, along with a pertinent bibliography, which it is believed will assist in the selection and application of cooling towers in the condenser circulating-water cycle.

THE application of cooling towers in the circulating-water systems of steam-electric generating stations, until very recently, has been confined to those installations inaccessible to rivers or large bodies of water. Over the years, the cooling tower generally has been regarded as a necessary evil by the few and ignored by the majority.

With the doubling of installed capacity by the power industry in the past 10 years, and the parallel growth of all American industry, the abundant supply of once-through circulating water has all but disappeared. Available plant locations with sufficient surface water are now apt to be economically unattractive because of such factors as high cost of site, heavy transmission-line charges, and increased fuel-transportation costs.

Therefore, the cooling tower has become an integral piece of steam-electric station equipment of importance to almost every utility system in the United States. It is often the key to the intelligent economic choice of new plant location as well as the solution to problems of existing plant expansion.

The purpose of this paper is twofold:

(1) To discuss the more important factors concerning the economic application of cooling towers in steam power plants.

(2) To discuss the selection of the cooling tower for a given set of plant requirements.

Evolution of the Modern Cooling Tower

The type of industrial cooling tower first widely employed was the natural-draft tower, which relied on natural circulation of the cooling medium, air and employed little engineering. Although no power expenditure for moving the air was required, performance was unreliable as it was entirely dependent on wind and at-

* Presented at the First Power Conference, Power Div., ASME, Allentown, Penna., Oct. 21–23, 1957.

† Chief Engineer, Cooling Tower Div.

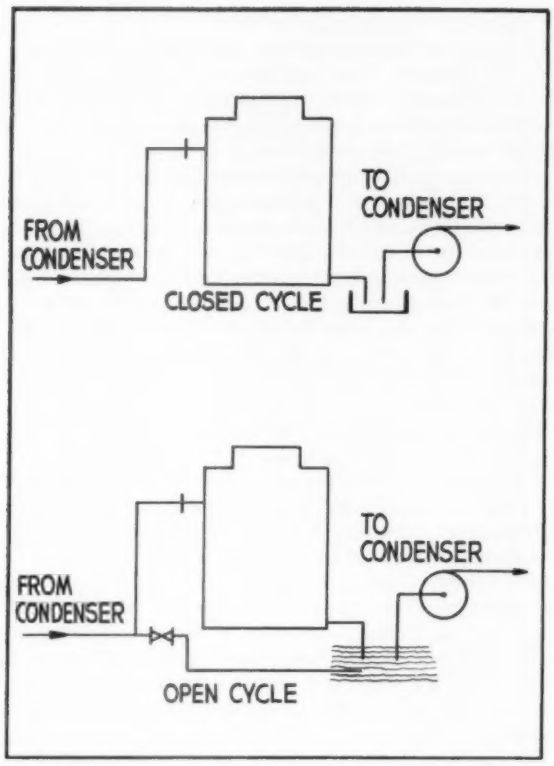

Fig. 2—Schematic of open and closed circulating water cycles

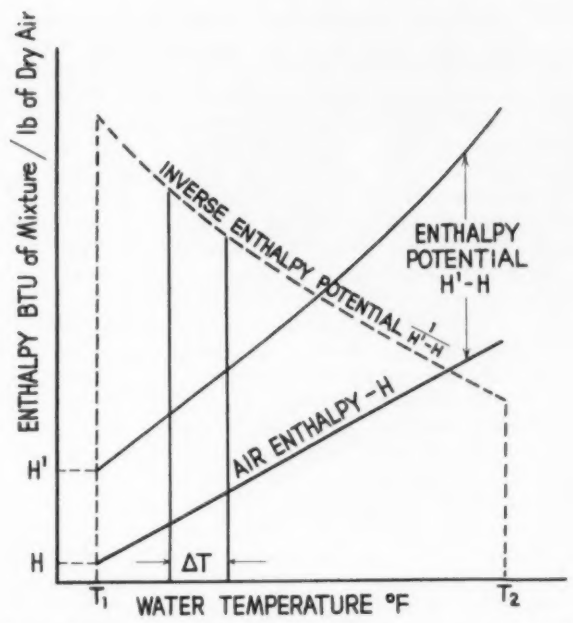

Fig. 4—Graphical integration method in determination of value of KaV/L

in Steam-Electric Stations*

mospheric conditions. The towers were comparatively tall structures, with resulting high circulating-water pumping costs. Spray losses were high, thus requiring excessive makeup, and often proved a nuisance with considerable maintenance cost on surrounding equipment.

Mechanical-draft towers of the forced-draft type were next introduced. By forcing the air through the tower at a known rate, a more predictable performance could be obtained. Fan and drive equipment, at ground level, were convenient for inspection and maintenance. Power consumed in pumping head was greatly reduced. Serious disadvantages, however, were still encountered. The distribution of air over the effective ground area of the tower cell left much to be desired. The fans tended to induce the discharged vapors from the top of the tower back into the tower, resulting in a prohibitive recirculation effect. This design of tower did not lend itself to effective use of the larger diameter fans being developed.

The induced-draft tower has evolved and, in the United States, is used almost exclusively today. This design mounts a large-diameter fan of high capacity atop the cell, with a properly designed fan stack, entrance throat, and plenum chamber. The arrangement assures even distribution of air flow throughout the effective cooling volume of the cell. Drift eliminators of the impact type are employed to minimize water loss by entrained droplets in the discharge air stream. The circulating water is distributed evenly above the packed volume of the cell and is broken up initially into droplets by either pressure spray nozzles or gravity-type down spouts and splash plates. The cooling volume of the cell houses the fill or splash bars. These decks serve to break up the falling water repeatedly, thus exposing the maximum water surface for the maximum time to effect evaporative cooling with the incoming air. Some film-effect heat transfer occurs at the splash bars, but most of the evaporation occurs at the surface of the falling water drop. The incoming air is introduced through louvered sides of the cell below the packed cooling volume in the counterflow type of tower and opposite the fill in the cross-flow design.

The unavoidable disadvantages of the induced-draft tower, namely, the higher power consumption required to pump the hot air rather than the cold air, and the fact that the mechanical equipment is less accessible, are more than offset by its lower initial cost and better air circulation and distribution characteristics.

Expanded Application of Cooling Towers

The increased use of cooling towers in generating plants having a natural water supply is an interesting new application, Fig. 1, p 41. There are many reasons which make this type of arrangement necessary or attractive.

In the majority of highly industrialized States "heat" itself is considered as a "substance" and, as such, falls under the regulation of the pollution-control boards.

There have been instances where various species of fish have been killed because of the temperature rise of the river attributed to the operation of one particular plant. The increased temperature, coupled with such other factors as high concentrations of organic materials and slowly flowing water, reduces the oxygen content of the water sufficiently to suffocate the fish. This situation may be brought about by industrial expansion along the river, increased sewage effluent, or periodically reduced water flow in the river. Sufficient pressure can be brought to bear on a plant to require a cooling-tower installation for operation during the critical months.

In the majority of cases, however, the cooling tower is employed when an existing generating station is expanded and the water flow in the river is not sufficient to provide the necessary condenser circulating water during the summer months. Expanding an existing station is in many instances more economical than building a new generating station at a new site whose only advantage is the availability of a natural source of circulating water.

Many of the aspects to be considered in balancing the feasibility of expanding an existing situation located on a river by providing a cooling tower for summer service versus building a new station on another river location have been discussed in a paper by Mr. Gausmann of the Indianapolis Power and Light Company (1).[1]

For the economics of that particular utility, the break-even point in selecting a new site on a river versus a cooling-tower installation are given as follows:

(*a*) Increasing the transmission line length by 14 miles.

(*b*) Or increasing the coal cost by 33 cents per ton.

(*c*) Or increasing the plant costs by $6.95 per kw.

If, in addition, the consideration includes the question of adding to an existing station as opposed to building a new station, the use of a cooling tower becomes even more attractive. "First cost" savings that can be realized in extending an existing plant consist of:

(*a*) Use of existing maintenance facilities.

(*b*) Partial use of existing fuel-handling facilities.

(*c*) Use of existing land for plant and transmission right of way.

(*d*) Partial use of transmission facilities.

Annual costs can be reduced by:

(*a*) Limiting supervisory and maintenance personnel.

(*b*) Elimination of any increase in transmission losses.

In most cases of summer standby cooling-tower use, the open circulating-water cycle is maintained, Fig. 2, and the cooled water is returned to the river. This arrangement makes the maximum use of existing circulating-water facilities and requires only a minor investment in piping, valves, and booster-pump capacity.

In some localities river flow may all but disappear for a few months a year, and the standby tower must of necessity be on a closed circulating-water circuit with the condenser, Fig. 2. The considerable additional investment that this arrangement requires, however, can be somewhat offset by taking advantage of higher velocities in the condenser.

Circulating-water velocities with river water are usually limited to 6 to 7 fps because of condenser-tube erosion problems. Operating on a closed system this velocity can be increased safely to 8 fps with an appreciable improvement in station heat rate. A typical set of figures illustrating this point is given in Table I. It will be noted that an inlet-water temperature of 90 F is used for both river water and cooling-tower water. This is justified since the cooling tower can be chosen economically for 90 F cold water, which represents a 14 deg F approach to a typical 76 F wet bulb. For the problem in question, it is not at all unusual for the river water to reach a temperature of 90 F.

The City of Lansing, Mich., made some interesting studies recently to determine its future course in greatly expanding the Moores Park Station (3). The major factors considered are listed in Table II.

In the first part of Table II the possibility of recirculating the water upstream and using pond cooling is considered. Since this would require evaluation on the basis of final station capacity, the estimate is based on four times the water flow required by the immediate expansion planned. To implement this scheme a 72-in. line 6 miles long would have been required. In the second part of Table II the advantage of installing the cooling tower rather than building a new station is shown. In this particular instance, the lack of water flow in the summer time made one of the alternatives mandatory. The cooling tower, using an open cycle, was chosen as the best economic solution for this particular set of conditions.

Numbers in parentheses refer to the Bibliography at the end of the paper.

TABLE I—EXAMPLE OF IMPROVED STATION HEAT RATE THROUGH INCREASED WATER VELOCITY IN CONDENSER

Assumed size of condenser—80,000 sq ft, two pass, 7/8 in.—18 B.W.G. tubes 28 ft long; inlet water temperature 90 F; 85% tube cleanliness.

Assumed size of turbine—1500 MW; 2—26-in. exhausts; steam conditions—2000 psig 1050/1000 F.

	River	Cooling Tower
Water velocity, fps	6.5	8.0
Water flow, gpm	60,000	73,600
Increased pump power due to increased dynamic head and flow, kw	0	31
Back pressure at design operation, "Hg	3.28	2.88
Change in gross turbine heat rate (2), Btu/kw-hr	0	(−)73
Change in station heat rate, Btu/kw-hr	0	(−)92
Fuel savings on basis of 3 months operation @ 70% load factor, 15% capitalization rate, 30¢/million Btu fuel cost, $	0	42,300

TABLE II—TYPICAL CONSIDERATION OF ALTERNATIVES IN EVALUATING COOLING TOWER INSTALLATION ON RIVER LOCATION

	Building New Plant at New Site	Cooling Tower Installation at Existing Plant	Recirculation of River Water to Obtain "Pond Cooling" in River
Four Unit (176,000 Kw Total) Expansion			
Installation Cost	...	$1,120,000	$2,906,000
Annual Operating Cost (2200 hr per yr)	...	130,000	211,000
Total Annual Cost (Capitalized @ 15%)	...	298,000	647,000
One Unit (44,000 Kw) Expansion			
Installation Cost			
Plant & Equipment	$10,000,000	$9,117,000	...
Cooling Tower	0	302,000	...
Transmission Line	1,300,000	0	...
Total	$11,300,000	$9,419,000	
Annual Operating Cost			
Cooling Tower	0	$ 35,000	...
Transmission Loss	89,000	0	...
Additional Labor	400,000	0	...
Total	$ 489,000	$ 35,000	
Total Annual Cost (capitalized @ 15%)	$ 2,184,000	$1,446,000	...

Establishing Design Requirements

The economic aspects and variables for obtaining the optimum selection in balancing the cooling-tower size, the condenser size, and the turbine-exhaust size have been discussed in previously published papers (2, 4, 5). This investigation can, by itself, be an exhaustive study. However, the effect of the cold circulating-water temperature on the station heat rate has become more pronounced with the more efficient units using high-temperature and pressure cycles. The tendency toward large units, using cross-compound turbine-generators with low-speed, large-diameter, exhaust wheels has brought about more effective use of low back pressures, and the judicious choice of approach and range for a cooling tower has become more important. Although the details of such an economic balance study are beyond the scope of this paper, there are a few fundamental practices with respect to the cooling tower that warrant discussion here.

For many years the choice of the design wet-bulb temperature has been based on a temperature not exceeded by more than approximately 140 hr per year. It has been suggested that the use of such a criterion for selecting a design value of wet bulb makes it very difficult to perform an acceptance test at or near the design conditions (6). If a wet-bulb temperature 5 deg F lower were used, the hours of operation at this design value would be greatly increased. Although it has been said many times before, it warrants emphasis in this connection that a lower wet-bulb temperature widens the approach for a given tower. Therefore, if an economic balance has been established which justifies a 12 deg F approach to a 79 F wet bulb, and it is desired to use a 74 F wet bulb as the cooling-tower design condition, the corresponding approach would be approximately 14 deg F. Assistance in determining this relationship of wet bulb and approach for a given tower size is readily available from the tower manufacturer.

Recirculation in cooling-tower terminology refers to the mixing of the warm vapors discharged from the tower with the colder surrounding air, resulting in an inlet wet-bulb temperature higher than ambient. Consideration of this effect must be made by the manufacturer in sizing tower to assure its satisfactory performance in relation to ambient wet-bulb temperature. The user, in locating the tower, should take certain precautions which will minimize recirculation and assure optimum performance. It is generally agreed that for towers up to 250 ft in length orientation of the long axis of the tower parallel to the prevailing wind is preferred. Towers longer than 250 ft should be arranged broadside to prevailing wind.

High structures close to the tower will divert the air discharged from the tower back into the air inlets and extraneous sources of heat will impair its performance. Therefore the tower should be as isolated as economics permit. When nearby heat sources cannot be avoided, the design wet-bulb temperature specified should reflect the estimated increase over ambient wet bulb.

Cooling Tower Institute Specifications

Since the founding of the Cooling Tower Institute in 1950 a considerable amount of time and effort has been spent to produce information useful to the cooling-tower purchaser as well as the manufacturer. Among the data published are:

(*a*) An acceptance test procedure for cooling towers (7).

(*b*) Specifications for redwood lumber for application in cooling towers (8).

(*c*) A report by a technical subcommittee on wood maintenance in cooling towers.

The acceptance test procedure specifies the conditions under which a test may be performed, the acceptable instruments, the measurements and number of readings required per measurement to obtain reliable and consistent results.

The lumber specifications define the grades, the nominal sizes used in the industry and give the allowable stresses for structural use of the different grades of redwood.

The report on wood maintenance describes the various types of wood deterioration occurring in cooling towers and the probable causes of the deterioration (9).

In addition to the bulletins published, a number of research projects are being conducted by the CTI. Among them is a large-scale field study to determine the factors contributing to recirculation. A long-range project, started in 1951, is also in progress to evaluate the effectiveness of wood treatment, and the resistance to deterioration of various species of wood.

Hyperbolic Cooling Towers

The hyperbolic tower is a unique form of natural-draft design, making use of the stack effect of a hyperbolic chimney-type structure, Fig. 3, p 38. Air inlet, water-distribution system, and fill are essentially the same as in a mechanical-draft tower. The packed height and hence the pumping head are usually somewhat higher. These towers have been built as high as 310 ft,

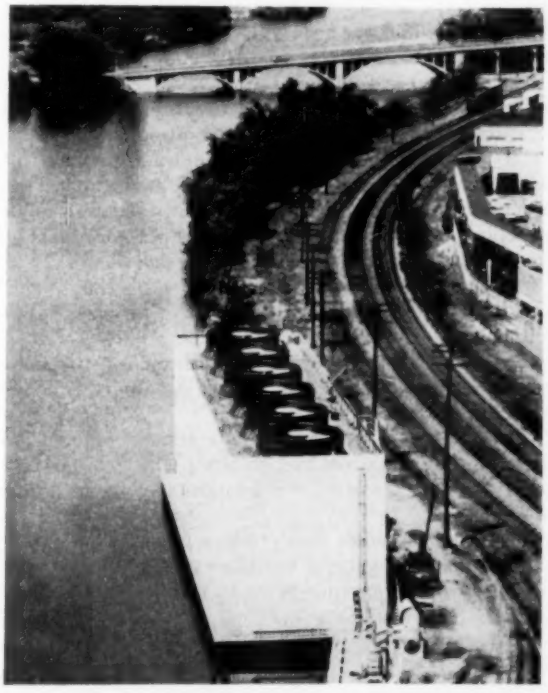

Fig. 1.—Summer standby cooling tower serving river steam-electric station

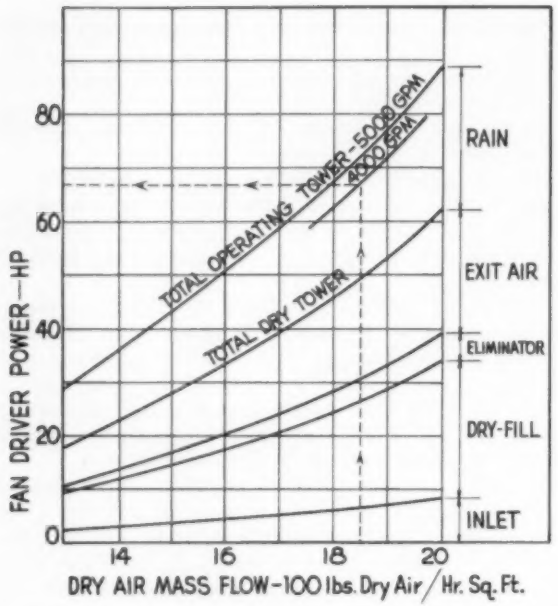

Fig. 6—Fan power requirements for components of a typical counterflow, induced draft cooling tower

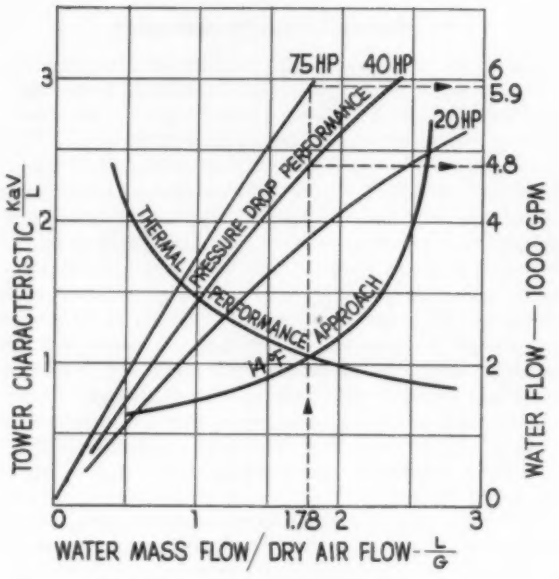

Fig. 7—Plot illustrating combination of thermal and fan power characteristics to directly determine flow capacities of a tower of given size

with a base diameter of 210 ft and a throat of 120 ft, widening to a diameter of 134 ft at the top.

The question is frequently raised as to why this design is so widely used in Great Britain and elsewhere, and yet is never seen in the United States. Despite the fact that the first cost of hyperbolic towers is one and a half to two times that of mechanical-draft towers, depending on the severity of cooling requirements, the British Electricity Authority has installed a large number of such towers in central stations throughout England. It is interesting to examine some of the factors which make this design attractive there and yet impractical in this country. Some of the considerations are:

(*a*) The wet-bulb temperatures are generally lower and consequently the approach to the cold-water temperature is increased. This wider approach causes a greater difference between the ambient and the exit wet-bulb temperatures, and consequently a greater difference in density. This improves the air flow through the hyperbolic tower, which is entirely dependent on the stack effect, and in fact makes this type of design possible.

(*b*) The wide approach, or in other words the "easier" cooling duty for a given heat load, keeps the size of these units within practical bounds.

(*c*) Station loads are lower during the summer than the wintertime and consequently loss of capability is not an important factor.

(*d*) Since these plants are government owned and operated, and no taxes are involved, the capitalization rate is only 7.5 per cent, which favors equipment of high initial cost (10).

(*e*) With fuel costs many times higher than in this country, the savings achieved through the elimination of any fan-power requirements are tremendous.

Determination of Tower Size

It is apparent that many different tower selections can be made to satisfy a given performance requirement. The cooling tower could have a large cross-sectional area with small fan-power requirements, approaching a natural draft tower as a limit, or a small cross-sectional area with large fan-power requirements. Similarly height and pumping head can be varied. It is our intent to show how various selections can be made. The optimum economic choice can then be made readily from among the many possible selections by balancing initial installation and operating costs. In briefly reviewing the underlying theory considered in commercial design, the factors that affect cooling-tower performance are:

(*a*) All conditions affecting thermodynamic behavior, such as packing configuration, and spacing.

(*b*) All conditions affecting air flow through the tower, such as type of fill rack used, fan efficiency, drift eliminator design, air-inlet louver design, and design of plenum chamber below fan deck.

(*c*) All conditions affecting the entering air, such as recirculation, external heat sources, and restricted free area around the tower.

Items (*a*) and (*b*) must, of course, be considered together, since they are interdependent. The purchaser can best compensate for the factors under item (*c*), which are beyond the control of the cooling-tower manufacturer, by adding the estimated increase in wet-bulb temperature to the design condition. Recirculation of the cooling tower on itself is allowed for by the manufacturer.

The thermal duty required of a cooling tower can most readily be put on a common ground by using the inverse of the enthalpy potential between the water and the cooling air. This method makes it possible to translate all the possible variations in range, wet-bulb temperature, approach and L/G to one common denominator, namely KaV/L. The theoretical proof for the validity of this method has been shown by many authors, and is accepted by most manufacturers (11, 12). The value of this thermal duty in terms of the tower characteristic of KaV/L can be calculated by various means. The differences in

the methods of calculation are not caused by a difference in theory, but one of obtaining the integral in the expression

$$\frac{KaV}{L} = \int_{T_1}^{T_2} \frac{dT}{H' - H} \qquad (1)$$

which can be integrated graphically, Fig. 4, or by a step method such as Gauss's rule or Simpson's rule, and still remain correct in a generalized way. Instead of using step methods of integration some authors have assumed an equation which fits the enthalpy of the air versus wet-bulb temperature curve for a limited range of temperatures (13).

The values of KaV/L for a range of operating conditions were put on 477 curves and published by the author's company in 1943. The maximum deviation from the true value of KaV/L is in the order of 5 per cent with the majority of values well within this limit. A typical curve is illustrated in Fig. 5. The use of these curves not only reduces calculating time materially, but gives a good visual impression of the effects that changes in design conditions have on the performance.

The performance of any given design of cooling tower can be expressed by the relationship

$$\frac{KaV}{L} = C\left(\frac{L}{G}\right)^{-n} \qquad (2)$$

where C and n are constants which vary for each tower. This performance can be represented as a curve on the coordinates of KaV/L and L/G. The results of test data for various fill configurations in terms of KaV/L versus L/G have been published (14, 15).

The thermal performance of a given tower for various operating conditions is thus completely determined, neglecting fan-power consumption for the moment. For instance assume that the equation of a tower under consideration is

$$\frac{KaV}{L} = 1.45\left(\frac{L}{G}\right)^{-0.55} \qquad (3)$$

and it is desired to determine the L/G ratio which would cause the cooling tower to operate at a 14 deg F approach, 15 deg F range, and 75 F wet bulb. By a few arbitrary assumptions of L/G the cooling-tower performance curve can be plotted. The 14 deg F approach curve can be plotted in terms of KaV/L versus L/G, keeping the range and wet-bulb temperature constant. The intersection of the two curves establishes the L/G ratio (1.78 in this case) that will provide the desired performance. The use of the published curves simplifies this procedure considerably. The approach curve is already plotted, and the tower performance curve can be drawn on transparent paper and used as an overlay. The proper L/G ratio is therefore immediately apparent.

The limiting quantity of water flow for the L/G ratio found is a function of the fan power only, and this ties the thermal performance to the pressure-drop characteristics of the cooling tower. The pressure drop through the tower consists of several components, as shown in Fig. 6, where the total is broken down to indicate the relative magnitude of each. With the exception of the pressure drop caused by the water (rain loss) each component has a certain velocity head, and the sum of the losses in the dry cooling tower require a fan horsepower

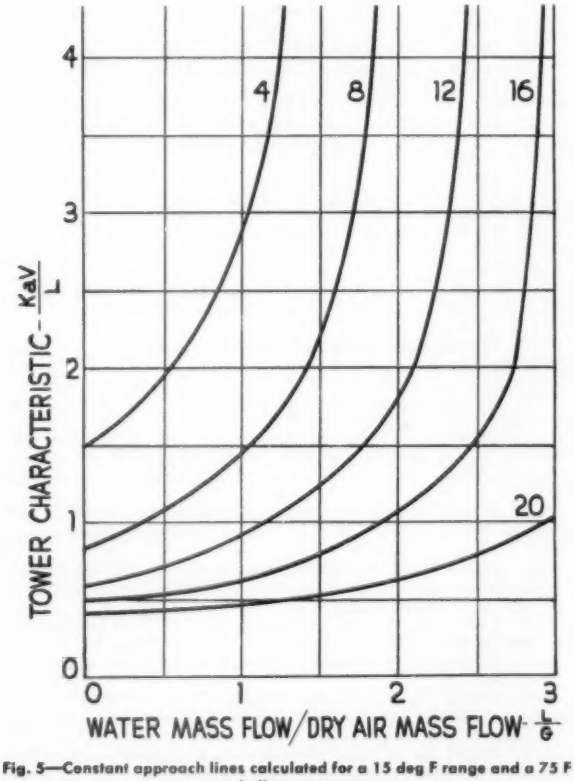

Fig. 5—Constant approach lines calculated for a 15 deg F range and a 75 F wet bulb temperature

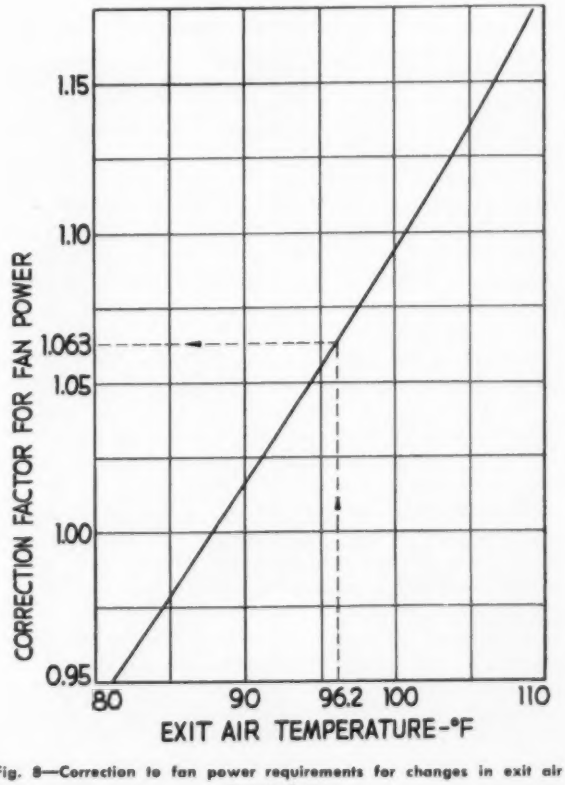

Fig. 8—Correction to fan power requirements for changes in exit air temperatures

expressed as

$$HP = d(G)^2 \quad (4)$$

where d is a constant characteristic of the cooling tower. The pressure drop caused by the rain is also expressed in velocity heads, except the relative velocity of water to air is used. This translates to an expression of the form

$$HP = eLG(G + S)^2 \quad (5)$$

Here again e and S are constants of the particular tower considered. By testing an existing tower without water, flow d can be found. By varying the air flow e and S also can be obtained. Depending on the use to be made of the final performance curves it need not be necessary to find all the constants. The curves shown in Fig. 6 can be translated to the common coordinate of L/G, and combined with the thermal performance, as illustrated in Fig. 7.

The L/G ratio found in the previous example did not establish the water flow, because the pressure-drop characteristic was not known. With thermal and pressure-drop characteristics for a given tower plotted on one "overlay," the water flow is fixed as soon as the economic fan horsepower is determined. Since the fan horsepower will change with air density, corrections to the plotted curves may be necessary if large variations are considered. The magnitude of this correction is shown by the curve in Fig. 8. This curve presents the horsepower multiplying factor versus the exit-air temperature. The exit-air temperature can be found from the enthalpy corresponding to

$$H_{exit} = \frac{L}{G} \times \text{range} + H_{inlet} \quad (6)$$

To illustrate the simplicity of applying the data presented the following is plotted in Fig. 7.

(*a*) The cooling-tower thermal performance based on equation (3).

(*b*) The 14 deg F approach curve for a 75 F wet bulb and 15 deg range.

(*c*) The fan-horsepower characteristic curves for this tower transposed from Fig. 6.

The exit wet-bulb temperature according to equation (6) corresponds to the enthalpy of $H_{exit} = 1.78 \times 15 + 38.61 = 65.31$ Btu/lb of dry air or 96.2 F where 38.61 corresponds to the enthalpy of air at a 75 F wet bulb, and 1.78 represents the L/G ratio obtained from the intersection of the thermal performance curve and the 14 deg F approach curve, and 15 is the chosen range. This requires a fan-power correction of 1.063, obtained from Fig. 8. In using Fig. 7 the plotted horsepower curves should be multiplied by 1.063 to account for the lower exit-air density.

Therefore the cooling tower in this illustration, after connecting for the exit-air temperature, can cool 3700 gpm with a 20-hp motor, 4700 gpm with a 40-hp motor, or 5800 gpm with a 75-hp motor.

The tower with the characteristics illustrated is far from being the only one that will give the required performance. Let us say that it is desired to determine, for economic evaluation, another tower that will give us 5800 gpm capacity with a motor smaller than 75 hp. Using Fig. 7 we can directly ratio the water flows at 75 hp and 40 hp, which is 5800/4700 or 123 per cent. Therefore, in order to find the new tower selection for 5800 gpm, it is only necessary to increase the motor horsepower to 49.4 hp and the ground area by 23 per cent, thus maintaining the same values of L/G and KaV/L.

An economic choice can then be made between the original tower with fan-power requirements of 75 hp, and the larger, greater first-cost tower, with the lesser horsepower operating cost.

Acknowledgment

The author wishes to express his appreciation to Mr. J. Arman for much of the data used to describe the hyperbolic cooling towers, and to Mr. D. E. O'Neil for his advice in the preparation of this paper.

Nomenclature

- a = area of transfer surface per unit of tower volume, sq ft/cu ft
- C = constant in equation (2)
- d = constant in equation (4)
- e = constant in equation (5)
- G = air-mass flow, lb dry air/hr sq ft ground area
- H = enthalpy of cooling-air stream, Btu/lb dry air
- H' = enthalpy of saturated air at water temperature, Btu/lb dry air
- K = overall transfer coefficient, lb/hr sq ft lb (water)/lb (dry air)
- L = water mass flow, lb/hr sq ft ground area
- n = constant in equation (2)
- S = constant in equation (5)
- T_1 = cold (exit) water temperature, deg F
- T_2 = hot (inlet) water temperature, deg F
- V = active tower volume, cu ft/sq ft ground area

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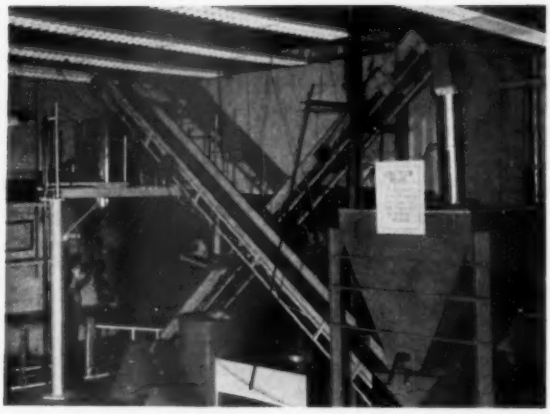

Fig. 1—Laboratory unit set up by BCR, above, included a test bin, Fig. 2

This paper presents and interprets test data from a range of coal sizes and moisture conditions that has led to the development of a special device or appendage to be added to the bottom of a conventional bin. The device is said to afford good control of flow from bin openings with freedom from arching and ratholing problems.

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Flow of Coal in Bins*

DESPITE the importance of bin design for coal and other bulk-solids storage, the design of most bins is still based on rule-of-thumb methods; and only recently has fundamental knowledge for use in design of bins become available. A. W. Jenike, J. C. Smith, and others have made recent contributions (1–6).[1]

The idea of pursuing a line of investigation similar to that of Jenike and Smith was considered. However, it was decided that a careful study of what was happening in a bin preceding, during, and immediately following inflow and outflow might be more fruitful, particularly if the study could be made with equipment somewhat larger than bench-scale size. After visits to many plants wherein problems connected with the flow of coal from storage bins were prevalent, it was concluded that a laboratory apparatus should be constructed whereby the flow patterns, pressures, and so on, could be observed and studied on a reasonable scale. It was assumed that many of the problems being encountered in the field were directly connected to the presence of $^1/_4 \times 0$-in. coal in the size mixtures being stored, and that a test bin sufficiently large to reduce to a minimum the effect of the coal-scale factor with this coal size would produce valuable information. Such was the course pursued, and the resultant patented flow-control device is the primary subject of this paper.

Test Apparatus and Coals Used

Test Apparatus. The test apparatus illustrated in Fig. 1 was constructed at the BCR laboratory in Columbus, Ohio. The actual test bin consisted of a 3-ft diam by 4-ft high vertical section to which could be bolted additional cylindrical sections or truncated-conical sections to enable multiple combinations of vertical and 45-, 60- and 75-deg hoppers. With the use of various combinations of vertical and conical sections, five different bottom-discharge openings between $8^1/_2$ and 30 in. diam were obtainable. The interior surfaces of the carbon-steel test bin were not smoothed, and the normal roughness of the construction, later increased by rust and fine-coal adhesion, was present.

Coal was handled to and from the test bin by means of flight conveyors. A 4000-lb capacity surge bin was provided for storage of the test coal. Water additions to the coal were made by spray nozzles located above the conveyors, and provision was made for sealing the surge bin so that uniform wetting of the coal could be accomplished by allowing it to set for a period of several hours. After discharge from the test bin outlet, coal was handled by various methods, including free fall to the laboratory floor, hand scraping on an inclined plate, a flight conveyor, and a convergent volumetric feeder. Coal could be fed to the test bin at rates between 100 and 950 lb per min, with a free fall from above the top of the bin of 10 ft maximum and 2 ft minimum.

Fig. 2 is a close-up view of the bin itself. The total coal

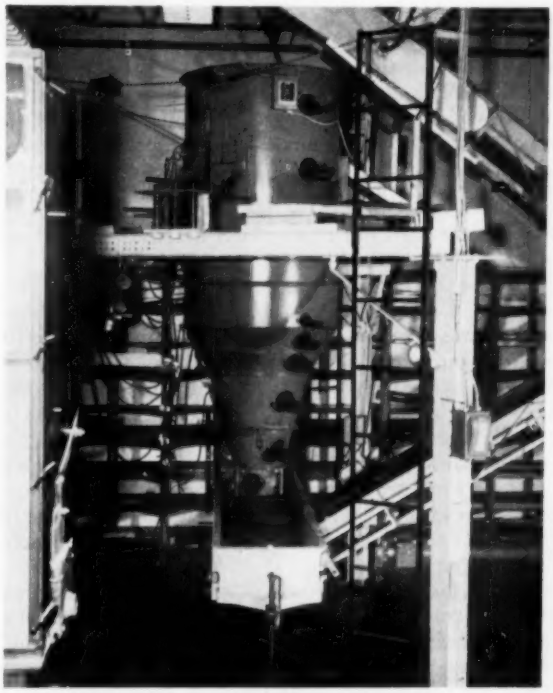

Fig. 2—The test bin consists of a 3-ft diam by 4-ft high vertical section to which can be bolted cylindrical sections or truncated conical sections for various hopper combinations

† Project Engineer.
†† Assistant Director of Research.
* Presented before the ASME-AIME Joint Fuels Conf., Quebec, Canada, Oct. 10–12, 1957 as paper No. 57-FU-2.
[1] Numbers in parentheses refer to the Bibliography at the end of the paper.

TABLE I—COALS USED IN LABORATORY TESTS

Coal No.	Nominal Size	Rosin-Rammler Data: Distribution Coefficient	Rosin-Rammler Data: Absolute Size Constant-inch	Remarks
1	1/4 × 0 in.	1.071	0.063	Hammermilled West Virginia high volatile
2	1/4 × 0 in. plus 1/16 × 0 in.	0.975	0.055	20 vol. % 1/16 × 0 in., 80 vol. % 1/4 × 0-in. hammermilled West Virginia high volatile
3	1 × 1/4 in.	2.280	0.535	Weathered Indiana No. 5 stoker
4	1 × 0 in.	0.910	0.205	Equal volumes coals No. 2 and 3
5	1/4 × 0 in.	1.000	0.049	Feed to coal dryer 1/4 × 0-in. plus filter cake, Rochester and Pittsburg Coal Co.
6	30 mesh + 0	0.833	0.0096	Filter cake Island Creek Coal Co.
7	1 1/4 × 0 in.	0.926	0.728	Eastern Gas & Fuel Associates Federal Mine, Grantown, West Virginia
8	3/8 × 0 in.	0.780	0.094	Pocahontas No. 3 seam Bishop, West Virginia
9	1/4 × 0 in.	0.986	0.065	Hammermilled West Virginia high volatile
10	3/4 × 0 in.	0.760	0.118	West Virginia high volatile screenings
11	3/16 × 0 in.	0.873	0.043	Cyclone-burner feed from crushed Alabama strip mine coal
12	2 × 3 in. egg	...	2.70	High volatile Eastern Kentucky

Fig. 3—Above presentation of the coals employed in the tests indicates something of their prior preparation but does not list the wide variations in range of surface moisture contents

capacity was 2800 lb when filled without compaction with 1/4 × 0-in. coal containing 10 per cent total moisture. Flush-mounted pressure gages were located in the vertical and conical bin walls. Openings also were provided for horizontal core sampling and for introducing gages for readings vertical pressures at 6-, 12- and 18-in. distances from the bin wall at six different elevations. Pressures on the water-filled 4- and 5-in. diam gages were indicated by vertical manometers.

The test unit was saddle mounted on heavy vertical coil springs supported by a structural-steel tripod. When the unit was operated as a weigh system, net coal weights were obtainable to ±10 lb accuracy. Coal was sampled mechanically and by auger-equipped core tubes, for water determinations, size consist, and bulk density. Total moisture was determined by 16-hr drying at 200 F.

Coals Used. The coals used during the laboratory tests are shown in Fig. 3 (Table I). Various size consists as shown were tried during the later stages of testing and after the device described later was developed.

During the earlier stages of testing, coal No. 1 was used. A 4-ton sample of this West Virginia high-volatile coal was crushed in the laboratory hammermill to 100 per cent through 1/4-in. square screen. This provided a test material having a Rosin-Rammler distribution coefficient of 1.071 and an absolute size constant of 0.063 in. To eliminate possible erroneous conclusions, the original crushed sample was split into two parts; the first half was used for repeated tests and the second half was used only to confirm that the results obtained were due to equipment design and not to changes in coal size consist, particle shape, and so on.

The surface moisture content of all the coals used was varied between 3 1/2 and 18 per cent (with exception of tests on coal No. 6 when 28 per cent was used) during different stages of the testing and development program. Fig. 4 is a typical plot of ASTM bulk density vs. surface moisture for the crushed West Virginia coal used in the majority of the tests.

Conventional Bin Studies

An extensive series of tests was conducted using the test apparatus as a conventional storage system with 45-, 60- and 75-deg hopper bottoms and various discharge opening diameters. Since the information obtained during these tests merely confirmed what the authors and others had observed in full-scale plant operations, this phase of the program will be covered very briefly here. The following summarizes the data and results when using the 1/4 × 0 Coal No 1, Table I, Fig. 3.

(1) With a 45-deg sloped hopper bottom and a 17-in. diam outlet opening, manual undercutting and probing along the edges of the outlet opening were required to insure flow with a coal having a surface moisture of more than 3.5 per cent.

(2) With 60- and 75-deg hopper bottoms, undercutting was necessary to obtain coal movement through 12-

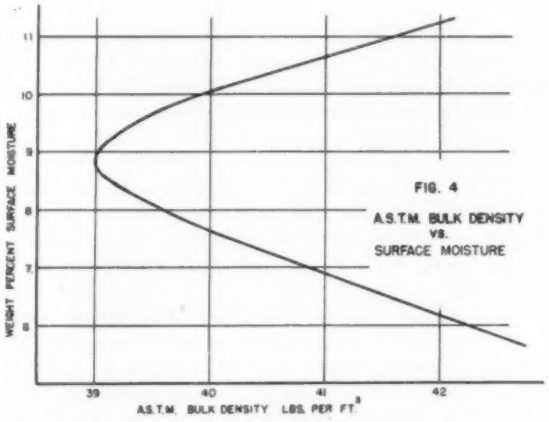

Fig. 4—Surface moisture content of coals in Fig. 3 were varied between 3 1/2 and 18 per cent (except No. 6 to 28 per cent). Above is a typical plot

and 17-in. diam openings when the surface moisture exceeded 8 per cent.

(3) During all tests, many arches were noted ranging from flat saucer to vaulted Gothic types. Ratholes also developed whose surfaces were not eroded by contact with moving coal after hours of operation using balanced input and withdrawal conditions.

(4) Using an "off-center" coal feed, it was possible to develop overhanging masses and coal ledges. In these test runs when funnel flow did develop, capacity utilization of the bin never exceeded 90 per cent, even with a maximum outflow rate of as high as 200 lb per sec. In most tests, the test bin delivered only 40 to 75 per cent of the contained coal.

(5) Fig. 5 is a plot of wall and vertical pressures at various elevations through the test bin with a 45-deg hopper and a 17-in. diam outlet opening. Pressures were not linear with coal depth or distance from the bin wall.

(6) Fig. 6 shows the changes in bin wall and internal pressures under (a) static conditions, (b) after the outlet closure had been opened, and (c) after vibrating the bin with the outlet closure open. During this test a 45-deg hopper bottom and 17-in. diam outlet were again used. The figure shows that pressures were increased without definite trend when the hopper-outlet closure was removed. After being subjected to vibration, the pres-

sures increased greatly without additional discharge of coal through the open outlet. However, despite the fact that the use of a vibrator caused great increase in pressures, the bulk density increased less than 0.4 lb/cf, or less than one per cent of the original coal bulk density.

(7) It was found that a combination hopper consisting of a 60-deg conical section between the 36- and 24-in. diam and a 75-deg conical section between the 24-in. diam and 12-in. outlet gave best performance.

From the nearly 150 tests run, it was concluded that poor flow performance of conventional storage bins is due to the presence of a central core movement responsible for ratholes and high pressures on and coal adhesion to the hopper walls. The solution to reliable solids flow is a cheap means to eliminate the central core and to provide an environment of low, steady pressures on the hopper walls, thereby obtaining plug-type motion through the entire bin and hopper.

Background Studies for Corrective Measures

In an effort to determine means for eliminating the central core movement and to provide the needed low, steady pressures on the hopper walls, a number of bin wall configurations and internally mounted devices were tried.

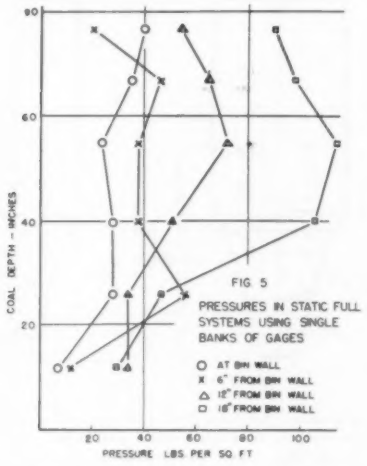
COAL DEPTH - INCHES
PRESSURE LBS PER SQ FT
FIG 5
PRESSURES IN STATIC FULL SYSTEMS USING SINGLE BANKS OF GAGES
AT BIN WALL
6" FROM BIN WALL
12" FROM BIN WALL
18" FROM BIN WALL

Fig. 5—Wall and vertical pressures within a bin having a 45 deg hopper bottom and a 17-in. diam outlet are plotted at various elevations

Central Core Flow Retarder. The first attempt to develop a method for overcoming central core-flow movement was the device illustrated in Fig. 7. Tests with this device proved that if the central core could be retarded, full movement of the coal at the bin walls would result and improved flow would be achieved. However, continuous withdrawal of the coal from the external conical surface would be impractical in the field.

Flat Plate. Using the test-bin configuration found to be most satisfactory during the testing of a conventional bin, namely the 36-in. diam vertical section with the combination 60- and 75-deg sloping sides, a series of tests was conducted using flat circular plates supported above the juncture of the vertical and sloping walls, Fig. 8.

Studies were then made using 17-, 20- and 24-in. diam circular plates rigidly mounted at elevations of 5 and 8 in. above the juncture. The 20 in. diam plate at 8 in. elevation gave best performance, enabling handling of coal containing up to 10 per cent surface moisture. During this series of tests, it was observed that flow of coal through the complete test bin was divided into two parts; namely (1) flow from the vertical section to the sloping hopper section, and (2) flow through the hopper section and out the discharge opening. While the use of the 20-in. diam circular plate gave improved flow from the hopper section through the outlet due to reduction in pressures, there was difficulty in the passage of coal from the vertical section to the hopper section.

Vertical Cap Cone. To improve the flow of coal from the vertical section of the bin to the hopper section, the use of a 60-deg sloping cone with 20-in. diam base was tried, as shown in Fig. 9. Tests of this idea showed that owing to the uniform coefficient of friction between the coal flowing over the cone and the coal flowing along the bin walls, reliable flow could be obtained from the vertical bin section to the sloping hopper section. Coals with moisture could be handled through this section of the bin. However, jamming of the coal occurred in the hopper section, again giving unreliable flow through the outlet.

Cap Cone with Lower Cylinder and Inverted Cone. In an effort to prevent the repacking of coal below the cap cone, a series of tests was conducted using the 20-in. diam cone as described to which was attached a cylinder and inverted cone as shown in Fig. 10. Tests with cylindrical sections of 10- and 14-in. heights proved ineffective, and resulted in wedging of the coal between the cylinder surface and hopper wall.

Cap Cone and Extended Inverted Cone. The next modification of the bin was the installation of the 60-deg cap cone of 20-in. diam and an inverted cone extending from the base of the cap cone to within 2 in. above the outlet opening, as shown in Fig. 11. As soon as testing was started on this idea, it became apparent that the basic design features to enable elimination of the central core movement and to provide an environment for low, steady pressures on the hopper walls was being approached. With the bin design shown, it was possible to obtain re-

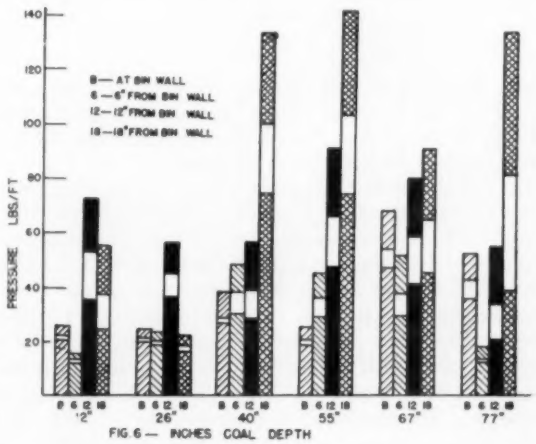

Fig. 6—Changes in bin wall and internal pressure are pictured (1) under static conditions (2) after opening outlet closure (3) after vibrating the bin with closure open

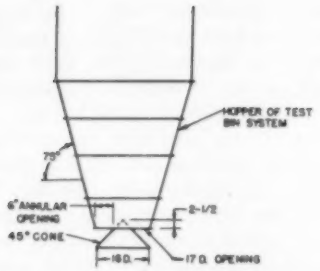

Fig. 7—First attempt to overcome central core-flow movement was the above 45-deg cone with a 6-in. annular opening

liable flow with $^1/_4 \times 0$-in. coal containing as high as 12 per cent surface moisture at flow rates up to 2500 lb per min through an $8^1/_2$-in diam outlet opening. Coal Nos. 1 through 4 and 12, as shown in Fig. 3 (Table I), were tried in this particular unit.

Flow of coal from the vertical bin section to the sloping bin section was very reliable, and was accompanied by a rolling effect of the coal at the hopper walls. The flow of coal through this section was essentially plug-type flow. The coal passing through the hopper section into the outlet was loose and fluffy, and no changes in pressure in the hopper section occurred when the loading above the hopper section was increased.

During the tests conducted with this design, it was found that the optimum location for the juncture of the 2 cones was 8 in. above the juncture of the vertical bin and sloping-wall section, and that the location of the apex of the inverted cone at the same elevation as the outlet opening gave best results. The 20-in. diam for the cone base proved satisfactory for all coals tested. Bin, hopper wall, and outlet-closure pressures under static full conditions were considerably less than without the cones installed. The comparative pressures show in Fig. 12.

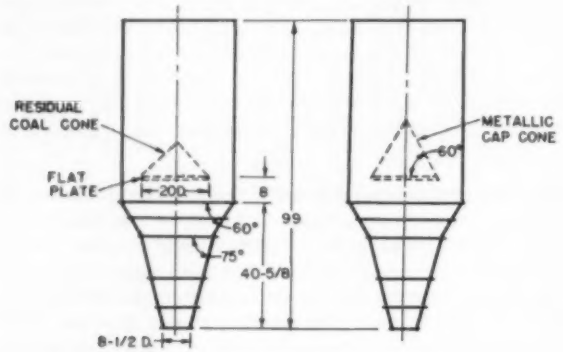

Fig. 8–9—Using the test bin configuration found most satisfactory a series of tests with flat plates, Fig. 8, were run and later a 60-deg sloping metallic cap cone was tried

Bin Discharge Modifications

12-in Diam Outlet and 77-deg Cap Cone. While the bin and cone designs last described would handle $^1/_4 \times 0$-in. coal containing up to 12 per cent surface moisture, further experimentation showed that the moisture content could be increased to 14 per cent with the design shown in Fig. 13. Changes over earlier designs included: (a) The installation of a 77-deg cap cone to improve flow from the vertical bin section to the hopper section. (b) The use of a 12-in. diam outlet to improve flow through and from the hopper section.

75-deg Sloped Hopper. As pointed out earlier, the development of the internal-cone designs evolved about the use of a combination 60-deg and 75-deg hopper bottom, because this particular configuration had given most successful results without cones installed. With the use of appropriate cones this type bin gave good flow characteristics, but some residual coal remained after emptying, this coal being supported by the 60-deg sloping sections. The use of 75-deg sloped hopper with 60- and 77-deg cap cones was then investigated.

This design, as shown in Fig. 14, with a 60-deg cap cone, gave good results with surface-moisture contents up to 13 per cent. The 75-deg sloped hopper with 77-deg cap cone as shown in Fig. 15 proved ultimately to be the optimum design, and enabled the handling of $^1/_4 \times 0$-in. coal containing 15 per cent surface moisture.

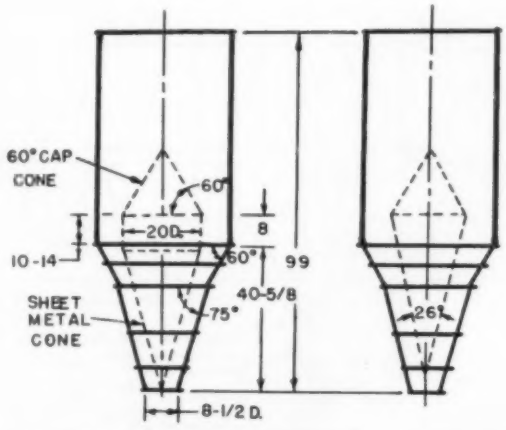

Fig. 10–11—To prevent repacking of coal beneath the cap cone, Fig. 9, a cylinder and an inverted cone was added and tested out. It was later modified, Fig. 11, with an inverted cone

All the coals described earlier, Fig. 3 (Table I), were handled successfully through a bin of this design. Coal No. 6, having 28 per cent total moisture, flowed reliably when the vibrator was operated continuously. Wall pressures above and below the junction of the bin and hopper sections were 15 to 25 lb per sq ft at completion of filling, and decreased to 5 to 15 lb per sq ft after starting and during coal outflow. Vibration during filling, after filling, and during discharge, as well as an extra 100-lbs per sq ft loading on the leveled top surface of a full bin, did not hinder the outflow of $^1/_4 \times 0$-in. coal.

Stainless-Steel Cones. The use of stainless steel rather than carbon steel for fabrication of the internal cones was investigated. For the cap cone, the use of stainless steel did not appear to be particularly beneficial. However, the use of stainless steel for the inverted cone is recom-

mended. The particular advantage in constructing this cone of stainless steel relates to start of coal flow after protracted retention periods. Coal stored in the test bin for as long as 10 days started to flow immediately upon opening of the outlet closure when stainless steel inverted cones were used.

Application to Other Bin Shapes. While the major portion of this program was devoted to the investigation of coal flow through cylindrical and conical-bottom bin combinations, the use of the idea in recent months has been applied to square and rectangular bins. Elimination of the central-core movement by cones, pyramids, and sloped deflector plates has made possible handling of $^1/_4$-in. coal at 10 per cent maximum moisture through a 2- by 2-ft square test bin having a 12-in. diam outlet. This same coal has been handled at rates up to 15,000 lb per min through a 48- × $5^1/_2$-in. outlet at the bottom of a 4- × 4-ft steel test bin. It is significant that at this extremely high coal-flow rate the shut-off gate could be closed by application of only 50-lb force on a 48- × 10-in. wide hinged closure.

The work on other than cyclindrical bins is still in the exploratory stages, but the authors are confident that the results of this investigation will prove beneficial in the handling of fine wet coal by utilities and in carbonization plants.

In conclusion, the authors wish to make clear that the development which has been described in this paper is not considered to be a laboratory device which can be scaled upward for application to large industrial storage bins. If scaled upward to fit the typical bin, the conical interior construction would occupy so much of the storage volume that its use would be impractical.

Rather, the device is an appendage which can be added to the bottom of a conventional-type bin. It provides the means for controlling flow from an opening in the bin, sufficiently large to prevent arching, to an $8^1/_2$- or 12-in. diam outlet which because of low pressures can be opened and closed by a relatively simple mechanism. In the laboratory tests, the top opening was 3 ft diam. Whether this opening should be 4 ft or 5 ft is not germane to the basic idea, but rather will be governed by the main bin design, headroom available, type material being handled, and so on.

The development we have described has not been explored fully. We plan to continue our work with it, and will welcome comments and suggestions from others active in the materials-handling field.

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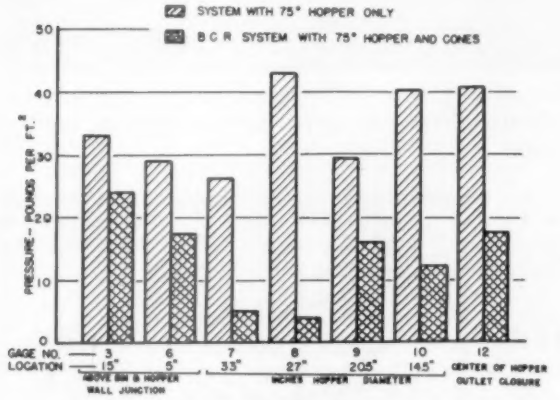
SYSTEM WITH 75° HOPPER ONLY
B C R SYSTEM WITH 75° HOPPER AND CONES
PRESSURE - POUNDS PER FT.²
50
40
30
20
10
0
GAGE NO. 3 6 7 8 9 10 12
LOCATION 15" 5" 33" 27" 205" 145" CENTER OF HOPPER OUTLET CLOSURE
ABOVE BIN & HOPPER WALL JUNCTION
INCHES HOPPER DIAMETER

FIG. 12 PRESSURE ON BIN AND HOPPER WALLS AND OUTLET CLOSURE FULL STATIC CONDITION

Fig. 12—Comparative static pressures on bin and hopper walls as well as the outlet closure show cones reduce pressures at all points

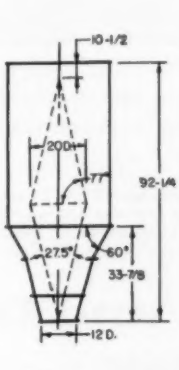

FIG. 13

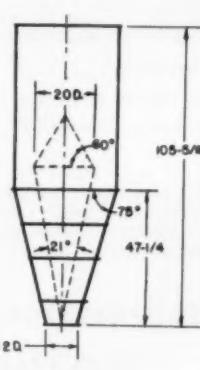

FIG. 14

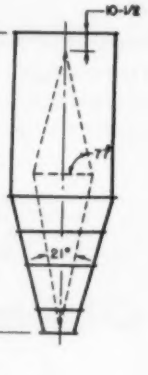

FIG. 15

Fig. 13-14-15—Final evolution stages of the cone and the hopper sides appear above with Fig. 15 the optimum, a 77-deg cap cone with a 75-deg sloped hopper

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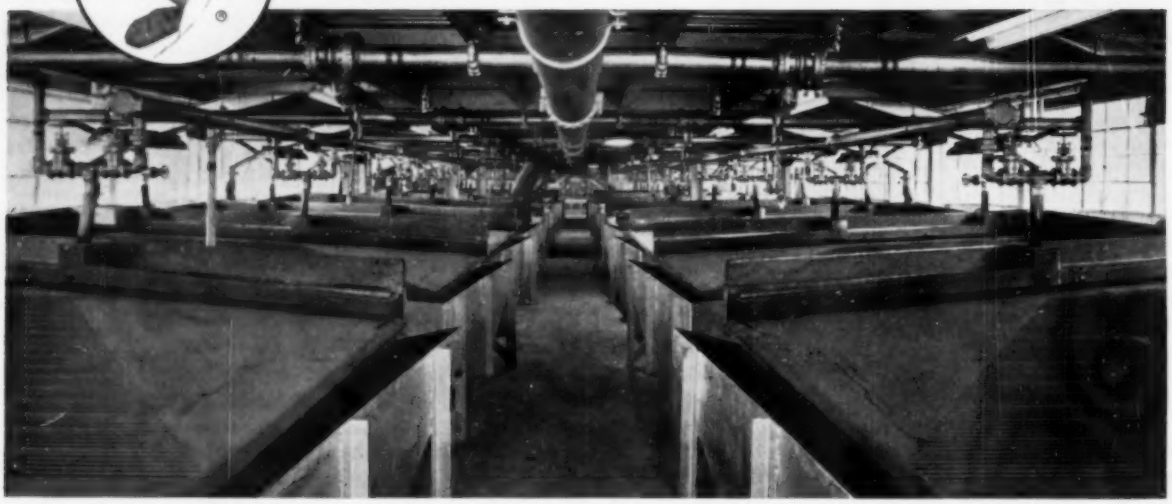

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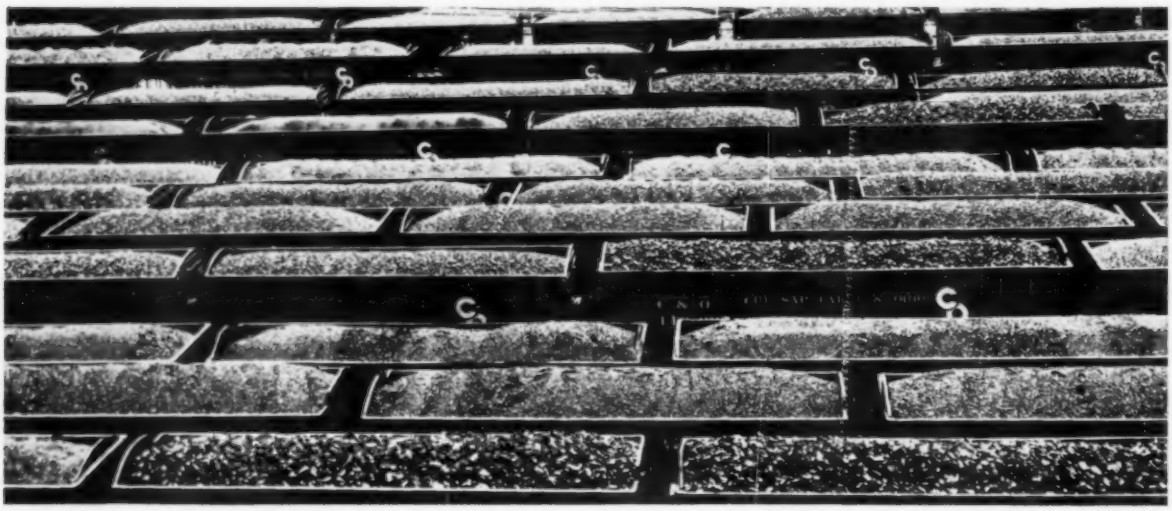

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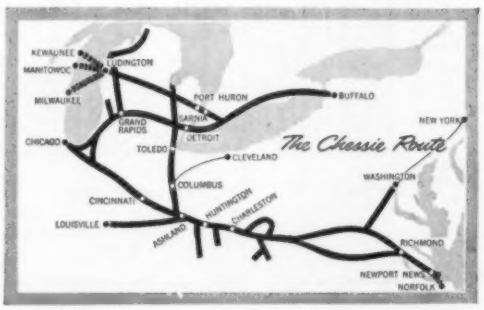

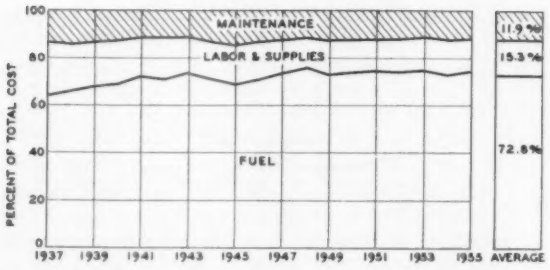

Fig. 1—Per cent distribution of production costs for thermal electric plants—Class A and B privately owned utilities

During the past two decades considerable progress has been made in the development and application of fundamental theory directed toward the production of electric energy at the lowest possible cost consistent with the requirements for service reliability. With some refinements, primarily the incorporation of transmission line losses and the development of computers the economic loading of generating stations and the incremental costs associated with the interchange of energy between interconnected systems today can be closely determined.

Incremental Maintenance Costs of Steam-Electric Generating Stations*

BY M. J. STEINBERG†

Consolidated Edison Co. of New York

WITH respect to fuel burning steam plants, production costs include fuel, maintenance, labor and supplies. Of these, fuel and maintenance will be affected most by a change in generation. Labor is not generally an element of incremental production cost unless the equipment in service is changed, and when this takes place, the associated labor cost is determined as a constant element independent of the change in generation. The cost of supplies is affected to a negligible extent, and for all practical purposes it may be omitted in the incremental production cost.

The distribution of production costs is shown in Fig. 1 for the Class A and B privately-owned companies, as reported by the Federal Power Commission for the 19 year period from 1937 through 1955.(1)[1] The distribution of production costs based on weighted averages for the period, are indicated to be

Fuel	72.8 per cent
Labor & Supplies	15.3 per cent
Maintenance	11.9 per cent
Total	100.0 per cent

With fuel as the major element of production cost, it is understandable why it is desirable to determine the incremental fuel costs with a high degree of precision, which is obtainable when adequate test facilities are available. With respect to determination of incremental maintenance costs, the general attitude differs somewhat. It is best expressed by the following quotation from a recent paper(2) which is devoted in part to the accuracy requirements of incremental production cost data.

"One of the elements of incremental production cost most difficult to evaluate accurately is the incremental maintenance cost. Various approaches to this problem have been tried, but due to the time interval between the event contributing to a condition requiring maintenance, and the actual maintenance expenditure, none of them has proved completely acceptable. However, on the American Gas and Electric system the magnitude of incremental maintenance cost in comparison with incremental fuel cost is relatively small (10% or less), so that a rather large error in incremental maintenance cost would result in a minor loss of economy due to the resulting misloading."

Although it is possible to establish with acceptable precision the hourly fuel costs expressed as a function of the kw load generated, from which the conventional incremental unit fuel cost data can be derived, no acceptable method has as yet been developed for establishing a similar reaction for maintenance costs. It has become, therefore, almost the universal practice to estimate incremental maintenance costs as a matter of judgment, the exercise of which is based to a large extent, on prevailing maintenance costs as carried on the books of account. It is the purpose of this paper to offer some comments on the use of statistical cost data for the purpose of approximating incremental maintenance costs.

Accounting Records of Maintenance Costs

Under the prescribed uniform system of accounts, maintenance costs are classified under the following:

Supervision and Engineering
Structures and Improvements

TABLE I—MAINTENANCE ITEMS AFFECTED BY VARIOUS FACTORS

	A	B	C	D
	Plant Capacity, Kw	Actual Peak Load Provided for Kw	Hours/Day Peak Load Prepared for	Generation, Kwhr
Boiler Plant Equipment	Yes	Yes	Yes	Yes
Turbo-generator Equipment	Yes	Yes	Yes	No
Electric Generating Equipment	Yes	Yes	Yes	No
Accessory Electric Equipment	Yes	Yes	Yes	No
Miscellaneous Power Plant Equipment	Yes	Yes	Yes	No
Power Plant Structures & Grounds	Yes	No	No	No

* Presented at the AIEE Fall General Meeting, Chicago, Ill., Oct. 7-11, 1957.
† Division Eng., Systems Engineering Dept.
[1] Numbers in parentheses refer to References at the end of the paper.

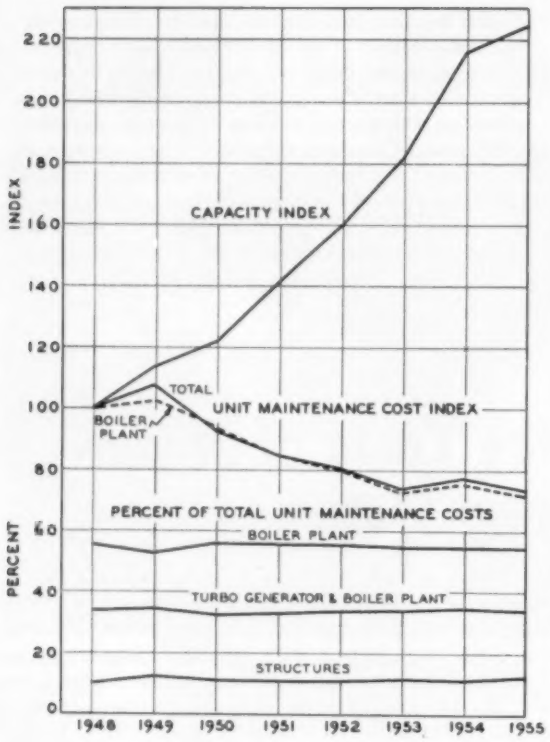

Fig. 2—Distribution of maintenance costs for ten power pools

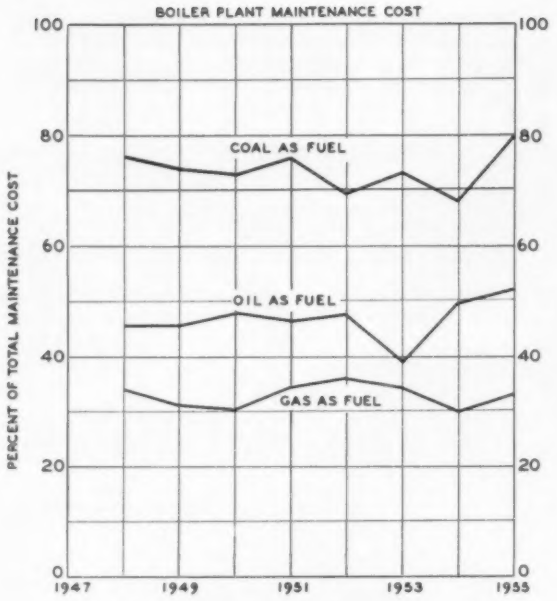

Fig. 3—Effect of type of fuel on boiler plant maintenance costs

Boiler Plant Equipment
- Coal storage, handling and weighing equipment
- Furnaces and boilers
- Boiler apparatus
- Steam piping and accessories

Generating and Electric Equipment
- Prime movers and generators
- Accessory electric equipment

Miscellaneous Power Plant Equipment

Under the format of the above, it is the general practice to provide an accounting system with subaccounts to permit distribution of maintenance costs among specific classes of equipment against which the costs are chargeable. It has been possible to extend accounting statistics considerably with the availability of large scale electronic data processing machines. One company reports(3) that monthly tabulations are made of some 200 separate maintenance accounts for each major plant. Such records permit extensive analyses of cost trends which are used to measure the effectiveness of methods to reduce maintenance costs,(3) for the determination of the economic need for design modification of existing equipment and planned additions, and for establishing company maintenance policy.(4)

The use of accounting records of maintenance costs require some caution. Extraordinary non-recurring maintenance expenditures should be excluded as well as expenditures for maintenance associated with capital expenditures, since these are not elements of incremental maintenance costs. To minimize the effect of deferred maintenance, costs averaged over a period of years, say 5 years, is recommended.

In the section following, several methods of utilizing records of annual maintenance cost are described without comment on their relative merits. It is expected that methods other than those described may be in use, and it is hoped that these will be presented in the discussion of this paper.

Methods of Calculation

In the absence of any exact method for determining incremental maintenance costs, the simplest solution of the problem would be to assume that the incremental unit maintenance cost is the same as the average unit maintenance cost. This could be justified on the basis that maintenance costs represent a relatively small percentage of the total production costs, or when a statistical analysis indicates a negligible variation in the average unit maintenance costs with variation of generation. In the latter case it is elementary theory to state that if the average unit costs for two levels of generation are equal, the corresponding incremental unit cost is equal to the average unit cost. This is demonstrated as follows.

Let

$A = A_1 = A_2$, the average unit cost at levels of generation E_1 and E_2, respectively

A_i = the average incremental unit cost for a change of generation from E_1 to E_2

Then

$$A_i = \frac{A_2E_2 - A_1E_1}{E_2 - E_1} = A\,\frac{(E_2 - E_1)}{E_2 - E_1} = A \qquad (1)$$

A refinement of the above method would be to exclude maintenance costs for equipment which are known to be unaffected to any appreciable degree by variation in generation. This would eliminate all items of equipment

except boiler plant, which includes fuel and ash handling equipment, boilers and furnaces, boiler apparatus, steam piping and accessories, and an allocated portion of accessory electric and miscellaneous power plant equipment. Application of this approach to one system was described in a 1938 article.(5) The influence of various factors on the maintenance of components of plant equipment is shown in Table I. The "yes" items under Columns A, B and C can be grouped to represent the component of cost, applicable when a change in generation involves a change in the combination of equipment in service. Column D can be considered as that component of cost which is affected by changes in generation only, and it is noted that the only item involved is the maintenance of boiler plant equipment.

An analysis of maintenance costs for ten large power pools for the eight-year period from 1948 through 1955 was recently published.(6) This shows some interesting trends which are indicated in Fig. 2. Distribution of total maintenance costs into components of boiler plant, turbo-generator and electric plant, and structures remained constant, not withstanding a capacity increase of 125 per cent above the value at the beginning of the eight-year period. The impact of the advancement in the art of design is reflected by the respective indices for total and boiler plant unit maintenance costs. The effect of type of boiler fuel on boiler plant maintenance costs is shown in Fig. 3. Each curve reflects the cost experiences of a specific power pool utilizing a single type of fuel. The burning of different types of fuel in combination or at different times results in maintenance costs which vary between the upper limit shown for coal and the lower limit shown for gas, depending upon the combination of fuels and quantity of each fuel.

The assumption that the incremental unit maintenance cost is equal to the average unit maintenance cost would not be valid in most instances. The average unit cost is subject to breakdown between "demand" and "energy" components, or "fixed" and "variable" components, with the latter generally considered as the incremental unit cost. A review of the available literature indicates two methods for determining the breakdown between the two components. One is arbitrary, involving the exercise of judgment, a typical illustration of which is the breakdown suggested by Justin and Mervine,(7) in the Table II. The other method is based upon some ex-

TABLE II—DIVISION OF PRODUCTION COST BY PERCENTAGES

	Fixed Cost, Per Cent	Variable Cost, Per Cent
Operation		
Superintendence	70	30
Boiler labor	60	40
Engine labor	100	0
Electric labor	70	30
Other labor	70	30
Fuel	15	85
Sale of ashes	15	85
Water	25	75
Lubricants	70	30
Boiler plant supplies	55	45
Boiler plant expenses	55	45
Other power plant supplies	55	45
Other power plant expenses	55	45
Superintendent's and other employees' expenses	70	30
Maintenance		
Power plant structures	100	0
Railroad sidings and trestles	50	50
Boiler plant equipment	55	45
Steam engines and turbines	55	45
Turbo-generators	55	45
Other electric generators	80	20
Other electric equipment	80	20
Coal storage and weighing equipment	50	50
Other power plant equipment	55	45

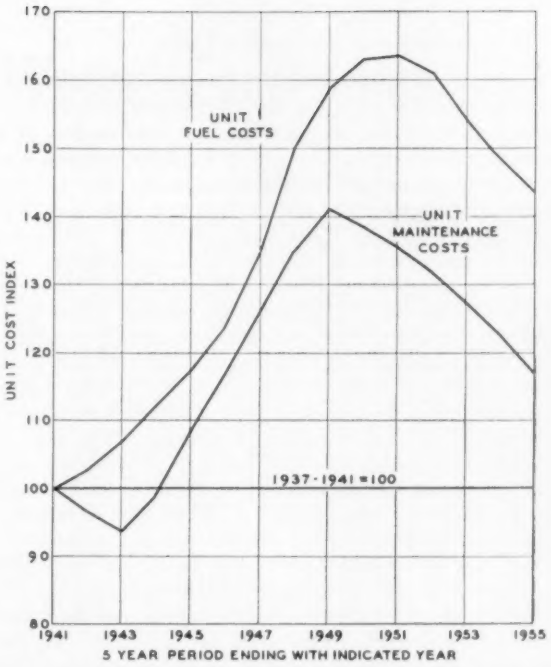

Fig. 4—Index of annual unit fuel and maintenance costs for thermal electric plants—Class A and B privately owned utilities

tensive mathematical analysis by Funk and Ralston.(8) A linear relation between annual costs in dollars, and annual generation is established. The no-load intercept is considered as the fixed or demand component of cost. The slope of the straight line gives the incremental unit cost. To reflect the effect of plant capacity and the peak prepared for, the no-load component of annual cost is subdivided into two components so that a linear equation is established as

$$A = K_1 + K_2 + K_3 \text{ (kwhr)}$$

where

A = Annual cost, dollars
K_1 = Component of annual cost related to capacity, dollars
K_2 = Component of annual cost related to peak prepared for, dollars

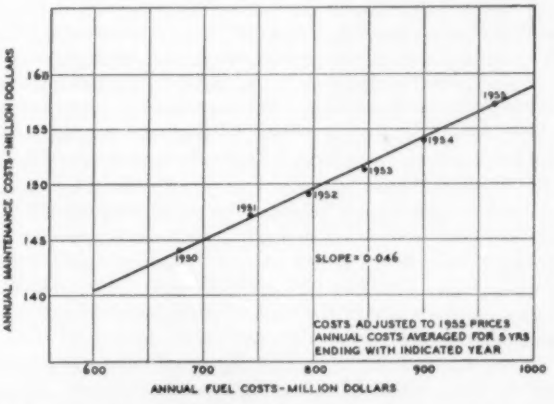
ANNUAL MAINTENANCE COSTS - MILLION DOLLARS
SLOPE = 0.046
COSTS ADJUSTED TO 1955 PRICES
ANNUAL COSTS AVERAGED FOR 5 YRS ENDING WITH INDICATED YEAR
ANNUAL FUEL COSTS - MILLION DOLLARS

Fig. 5—Ratio of incremental maintenance costs to incremental fuel costs for thermal electric plants—Class A and B privately owned utilities

K_3 = Incremental unit cost, $/kwhr

Use is made of the above method to establish an average incremental unit maintenance cost which is considered independent of the incremental unit fuel costs. It is included as a constant element of total incremental cost.

Analysis of annual cost data supports the inference that maintenance costs are not constant, but vary with fuel costs. This is illustrated by Fig. 4 which was derived from statistics for the entire industry as published by the Federal Power Commission for the years 1937 through 1955. Although the relation between incremental maintenance and fuel costs is not capable of exact determination, it can be approximated as previously described by the author in 1946 article.(9) Briefly, annual costs for fuel and maintenance are established graphically as linear functions of annual generation. The slope of the annual maintenance cost curve divided by the slope of the annual fuel cost curve is assumed as the ratio of incremental maintenance costs to the incremental fuel costs. Since both the annual fuel and maintenance costs are represented as linear functions of annual generation as the parameter, the annual maintenance costs can be established as a linear function of the annual fuel costs directly. The slope of this curve is then assumed to be the ratio of the incremental costs. The results of this method, applied on a nation-wide basis to the thermal electric plants of the Class A and B privately-owned utilities, are illustrated in Fig. 5. The results are of academic interest only in view of the many variables involved. It demonstrates, however, that the statistical annual fuel and maintenance costs for the industry as a whole, when adjusted to a common price level, will plot to indicate a linear relation between the two.

The magnitude of the allowance for incremental maintenance costs generally varies between 5 per cent and 30 per cent, depending upon the class of equipment involved, type of fuel and range of equipment loading. A survey of current practices in regard to determination of incremental maintenance costs would be beneficial to the industry, and this undertaking is therefore recommended.

Conclusions

Although fuel costs can be established as a function of the kw load generated with acceptable precision, no method has as yet been developed to permit determination of a similar relation for maintenance costs. Incremental maintenance costs are determined as a matter of judgment, based on past annual cost experiences. This is justified by the relatively small ratio of maintenance costs to total production costs. Annual costs of accounting record can be utilized to establish incremental maintenance costs at a fixed unit value per kwhr, or as a fixed percentage of the incremental fuel costs. On either basis, the precision of the derived value of incremental costs will be indeterminate. A survey to determine current practices in regard to determination of incremental maintenance costs is desirable.

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Converting Fly Ash to Road Materials

A cooperative research program by the University of Illinois and the Illinois Division of Highways it is hoped will permit converting the mountains of useless slag and fly ash at power plants into excellent cost-saving roads.

George W. Hollon, civil engineering instructor, has been studying and testing the material for more than a year. Further, a trial section of highway shoulder was laid recently near Chicago and another section of the new type road may be built next spring in Lake County.

Illinois power plants alone it is reported produce $1^1/_2$ million tons of slag and fly ash a year, and some pay up to $1.25 a ton to haul it away. Hollon estimates this would make 210 miles of 24-foot road, and that five miles can be built at the cost of three miles of standard main highway.

Lime is used as the cementing agent with the slag-fly ash. Besides low cost, the mixture has other advantages. It is not affected by outdoor temperature changes, an important cause of damage to present roads. It can be worked for up to 16 hours after mixing. This would eliminate mixers at the road building site. Ordinary dump trucks can haul the material from a central continuous mixer.

Because the slag-fly ash-lime mixture wears away easily, it must be surfaced with black-top. Many present black-top roads are on a portland cement base. This is where the new material has its promise.

Hollon says its particular value is for building secondary roads, city streets, and parking lots. Several lots are to be built soon in Chicago. Portland cement remains the material of first choice for heavy duty main highways.

Interestingly, the material is almost identical with that used by the Romans to build roads hundreds of years ago. Many of these still are in good shape. The Romans used lime with volcanic ash, which has chemical and physical properties almost identical with the slag and fly ash from modern power plants burning soft coal.

Eighteenth Annual Water Conference

THE well regarded Eighteenth Annual Water Conference sponsored by the Engineers Society of Western Pennsylvania was presented as usual in the Penn-Sheraton Hotel in Pittsburgh, October 21–23, 1957. Those papers held to be of interest to COMBUSTION readers are abstracted below.

Available Water Supplies

The now well-recognized fact that fresh water is a critical factor in our economy served as the basis for a session on ways and means of improving the supply situation. One such method incorporating a control of the losses from surface bodies such as lakes was discussed by **Robert R. Cruse,** Department of Chemistry and Chemical Engineering, Southwest Research Institute, in a paper entitled "Reduction of Water Losses by Retardation of Evaporation."

As Mr. Cruse pointed out in certain sections of the country the evaporation losses become astronomical. A recent survey for the state of Texas showed evaporation losses varying from 12 in. per year in the eastern part of the state to 108 in. per year in the western part. About half the state suffered 5 ft or more per year of loss from evaporation. Since an acre-foot of water represents about one-third of a million gallons this figure multiplied by the surface area of all the bodies of water in Texas truly reaches astronomical proportions.

The methods of reducing evaporation as the author sees it are:

(1) Reduction in surface exposed, i.e., digging reservoirs as deep as possible.

(2) Elimination of marine growths which pump a lot of water back into the atmosphere.

(3) Elimination of shallow water areas by dredging or excavation especially at the shore line.

(4) Recharging aquifers or storing water in underground reservoirs.

(5) Constructing wind breaks to cut down the air velocity across the water.

(6) Building roofs over reservoirs.

(7) Concentrating water in single reservoirs.

(8) Applying a continuous film across the water's surface to reduce evaporation rate.

Langmuir in 1917 made the first real study of such films and his concepts and measurements have proved remarkably good over the years. Of recent time the work of the Australians has been outstanding and the Southwest Research Institute, lately engaged by a special committee organized by public spirited individuals in the Southwest, has attempted to adapt the Australian findings to the Southwest. The problems this Institute has met were outlined and a report of the progress against these problems was submitted.

Certain discussors presented comments and reports on the experiences in various sections of the country to obtain greater water supplies through more effective recovery of waste waters or a greater use of waters before final discharge to waste.

Surface Condenser Tubes

A very comprehensive nine-paper session on the subject of surface condenser tubes was featured in a panel-like treatment.

Louis Caruso, Phelps Dodge Copper Products Corp., opened with the "Selection of Tube Material Best Suited for Water Conditions." Since there is no one tube alloy which can meet all operating conditions or water types in a superior way to all others the many factors such as corrosion resistance to the water type or the cost of corrective water treatment must be reviewed for all alloys. Mr. Caruso confined his discussion to the copper-base condenser tube experience with different water conditions. He then summarized his remarks and rated the selections he would recommend for salt water, brackish water, fresh water, recirculating systems, mine waters.

V. F. Nole, Chase Brass and Copper Co., Inc., followed with a paper, "Corrosion Phenomena in Condenser Tubes with Particular Reference to Copper Alloys." The various types of corrosive attack, general thinning, pitting, selective solution, stress corrosion cracking, intercrystalline corrosion, corrosion fatigue, galvanic corrosion, were described in quite some detail. The subject of pitting was especially so treated with Mr. Nole spelling out five forms of pitting and describing them along with some recommendations on means of combating the pitting action.

A. W. Tracy, The American Brass Co., discussed "Effect of Grain Size on Corrosion Rate of Copper Alloy Condenser Tubes." From a number of tests conducted in the author's company laboratories, certain conclusions were drawn and presented in this paper. Grain size whether uniform or nonuniform has no effect on the corrosion rates of the alloys tested, Mr. Tracy reported. Yet there are valid reasons for the inclusion of grain size limits in condenser tube specifications. The minimum grain size in ASTM Specification Bill-55 makes sure that the cold-worked metal has been recrystallized and is free from residual stress. The maximum grain size limit assures tube handling with a minimum of distortion.

"The Effect of Velocity of Acid Water on Condenser Tube Corrosion" presented by **J. P. Engle, C. F. Reich, A. C. Shoults,** Dowell Incorporated, was a report on a number of tests to determine how the corrosion rate of metals used in heat exchanger equipment is affected by circulating acid wash solutions. Turbulent flow rates, these tests indicated, did not unduly increase corrosion rates of the metals tested. In fact in their conclusion the authors express the opinion that heat exchangers containing the alloys tested (six in all) can be safely cleaned many times by circulation of hot, inhibited hydrochloric acid with much less metal loss than that experienced during operational periods.

The subject of "Effect of Ammonia and Some Amines on the Stress Corrosion Cracking of Copper Alloy Condenser Tubes" was handled by **Maurice C. Presley,** Scoville Manufacturing Co. His remarks were directed to tubes in the air boxes of steam condensers.

Ammonia and ammonia compounds, Mr. Presley pointed out, have a tendency to promote stress corrosion cracking of copper alloys. The tubes in the air boxes are in an environment of moisture from condensing steam, all the noncondensible gases, ammonia, O_2 and CO_2, some degree of tensile stress and a temperature of about 100 F, and hence incidence of failure runs high for these tubes. The author describes his findings and makes certain general precautionary measures that may be taken to avoid tube failures.

L. H. Hawthorne, Revere Copper and Brass, Inc., moved the discussion over to "A Résumé of Laboratory and Practical Experience in Welding Condenser Tube Alloys." The development of automatic welding equipment for tubes to tube sheets was brought up and the need to devise a satisfactory joint design procedure was advanced. The dangers of leakage from cooling water into the condensate as boiler-turbine cycles went to higher pressures and temperatures made a positive, permanent seal an important requirement for the condensers designed to serve these cycles. Much practical information obtained in the welding of the first welded surface condenser was supplied and considerable of this information received an analyzing in some detail.

E. D. Verink and **J. D. Rucker,** Aluminum Co. of America, raised the query "How About Aluminum Tubes?" The authors chose to present the questions most frequently asked about aluminum tubes and supplied answers to the most frequent thirteen.

Debris from normal operation, the authors state, has caused no trouble.

Normal design cooling water velocities for condenser service in power plants run 7 to 8.5 fps.

At Rockdale, 37 out of 22,000 aluminum tubes have failed from cavitation. All of these were in the first pass in an area adjacent to a 42-in. diam cooling water inlet.

Service lives of tubes 15–30 years have been established in the chemical and petroleum field. All aluminum heat exchangers have been added to the area of application and an installation at the Wisconsin Electric Power Co. as well as the Sandow Power Plant of the Industrial Generating Co., an affiliate of Texas Power & Light Co., employ aluminum tubes in their condensers.

Aluminum tubes may foul more readily than copper-base ones.

Heat transfer characteristics of new, clean aluminum heat exchanger tubes are identical with admiralty metal tubes.

Aluminum alloys possess outstanding resistance to CO_2, hydrogen-sulfide and ammonia.

With normal control on silica the aluminum content of condensate that has contacted aluminum surface condensers, and condensate storage tanks is sufficiently low to avoid analcite scale.

Service life with salt water has been reported by a number of chemical and process industries as exceeding 10 years in aluminum condensers with salt water cooling.

Aluminum tubes in existing power plant condensers have been installed with the same baffle spacing, tube hole clearance and pattern as for admiralty tubes. At Rockdale the first pass tubes were retubed and the experience showed tubes could be "stabbed" at a rate of 1000 tubes per shift with water lubrication only. Also it showed aluminum tube sheets could be reused successfully. With inserts in the inlets of all tubes aluminum and admiralty metal are on relatively equal footing.

Considerable work is under way to permit automatic welding of aluminum tubes to aluminum tube sheets.

Aluminum tubes are the least expensive heat exchanger tubes available.

Randolph V. L. Hall, Bridgeport Brass Co., discussed for his subject "Factors Involved in Overall Heat Transfer of Condenser Tubes." The problem of determining the degree of tube cleanliness obtained by ordinary maintenance cleaning or special chemical cleaning procedures has been met by one power company using a single-tube calorimeter, Mr. Hall reported. The method developed by Stawicki and Ungar was covered briefly.

The other factors of importance such as increasing the velocity or lowering the temperature of the cooling water, or removing air and other noncondensible gases, corrosion products and water deposits to improve heat transfer were mentioned. The recent attempts to improve the film coefficient of condensing steam with boiler and steam treatment for dropwise condensation was further discussed. A number of references were made to sources reporting on this work and hence the paper should prove valuable as a reference.

"The Effect of Condenser Design and Fabrication on Tube Life" was presented by **M. A. Nelson,** Westinghouse Electric Corp. There were two general approaches—(1) the circulating water system, and (2) the steam side.

Under these headings Mr. Nelson considered tube life, positioning of tubes, water boxes, water nozzle arrangements, venting and tube pattern for the water side and tube vibration, tube supports, the need for baffles, orientated subway grating, feedwater drain and makeup water locations for the steam side.

Nuclear Fuels

Atomics International has designed and constructed a sodium-graphite type of reactor for eventual tie-in with the Southern California Edison Co. and the last-named company has launched a number of studies to prepare for its operation. **Frank M. Eigner** of Southern California Edison Co. chose as his paper the "Water Treatment Problems of the Santa Susana Experimental Station."

Mr. Eigner opened his paper with a brief description of the plant cycle and then concentrated on the water conditioning. The steam boiler's once-through design imposed a very low total dissolved solids so hydrazine and morpholine were selected for pH control. Suitable conductivity equipment will provide the high degree of monitoring against inleakage of solids.

A. Louis Medin, Alco Products, Inc., reported in "Coolant Technology at the Army Package Power Reactor." Here oxygen is completely scavenged by hydrogen to minimize problems in the primary system. 1200 psi water circulates through the enriched stainless steel core at a rate of 4000 gpm. Continuous purification of this primary water is carried out and a portion is always removed through a bypass for repurification. This rate of repurification is fixed by the corrosion rate of the primary system materials.

Waste disposal problems tend to show up greenish in the demineralizer resins and hence radioactive build-up there becomes significant. A close radiation survey is

maintained at all times. Sometime between three to six months of service life and this radiation build-up is assumed to reach dangerous proportions. To attempt to regenerate the resins would be both dangerous and expensive so the demineralizer has been built as a completely disposable unit. It measures 12 in. diam., 36 in. high.

The secondary water system meets its first difficulty in the metal used to fabricate its steam generator—Type 304 stainless which is held susceptible to chloride stress corrosion. Failure, of course, would permit the radioactive primary water to enter. As a result, severe restrictions have been imposed on both construction and operation of the secondary system. Chloride concentration has been established at 0.5 ppm, and with a nominal blowdown rate of 1 per cent the feedwater must not exceed 0.005 ppm chloride.

Pilot Plant Operations

A panel discussion on pilot plant experiences was led off by **Richard J. Burrock** and **Joseph T. Yoder,** Minnesota and Ontario Paper Co., with the paper "Experiences Gained in Demineralizer Pilot Plant Operation." At this particular plant, lack of previous experience with local water supplies in demineralizers led to the decision to install a pilot plant. The information the pilot plant supplied was: (1) length of cation and anion cycles, (2) capacity and useful life of the resins, (3) the effect of organic fouling of the anion resin, (4) a method of recovering lost capacity caused by fouling, (5) the quality of effluent obtainable, (6) rinse characteristics of the resins and (7) operating experience.

The authors then describe the plant and the problems it would have when it was expanded. With this as a background they establish the nature of the pilot plant set-up and eventually the realization of the information this pilot plant supplied for the final plant as mentioned in the above paragraph.

H. C. Farmer and **V. B. Burgess,** Philadelphia Electric Co., in their paper, "Demineralizing Pilot Plant Studies at the Eddystone Station," early stated that the reason for their pilot plant project was the determination of a water suitable for the supercritical boilers now under construction at Eddystone. The pilot plant was set up on the site to obtain the same raw waters as the supercritical units would be called upon to use. The authors' company has had considerable experience with large scale two-stage, mixed bed and two-stage demineralizers followed by mixed beds. So the approach was to work through the different arrangements. Fouling of resin beds proved a major problem.

A sand filter was replaced by an activated carbon filter in one unit and another was interspersed between the zeolite softener and the second demineralized. It was determined to limit flow through the activated carbon and a top figure for this flow seemed to be 2 gal per sq ft per min.

The next step was a study of resins. The tests indicated an advantage for Type I anion resins to prevent fouling for this type of water.

Another test was for possible pickup by the water of organic materials from the resins. Results from these tests led to the desirability of discarding the effluent from the demineralizers during the initial phases of operation since most pickup occurred at this time. This water would be satisfactory for flushing when starting up new equipment.

In summation the pilot plant has convinced the Philadelphia Electric Co. that a combination of a 2-stage demineralizer equipped with a subsurface washer in the cation unit followed by the mixed bed demineralizer using the appropriate resins will give the best results.

Robert I. Smith, Public Service Electric and Gas Co., closed the formal part of the panel with his paper, "The Linden Generating Station Pilot Plant." This pilot plant embodying chlorination, clarification and filtration followed by cation exchange, vacuum degasification, combination weak base-strong anion exchange and mixed bed ion exchange was to provide operating information for a 3200-gpm full-scale plant.

Raw water supply could come from reservoirs where quality varied widely (rainy vs. drought periods) or from city water whose quality proved more uniform. Tests showed that substantial reductions in either extractable and organic matter could be made from the reservoir waters but complete removal was not indicated.

Further tests showed that the anion resin preceded by an activated carbon filter showed little if any capacity advantage over unprotected resin but the unprotected resin showed many indications of fouling tendencies.

With this as a background the pilot plant was built at a cost of $40,000. (Final evaluation after service tests were completed was set at $150,000.) Out of the plant came the answer to the fouling problem, which was a salt treatment every 5 to 10 cycles, a solution to certain control problems, an opportunity to test methods and instruments, a chance to train an operating crew.

Controls

The paper, "New Reins for an Old Horse" by **W. Wessing,** Polymer Corp. Ltd., and **J. C. Skerrett,** Hagan Corp. (Canada) Ltd., summarized the authors' experiences in developing conductivity control of a hot process lime and soda ash softener at the Polymer Corp. Ltd., Sarnia, Ontario. This plant is the only completely integrated synthetic rubber plant in the world in that its basic monomers used in processing are synthesized on the site. There are six boilers supplying an average load of 1,600,000 lb per hr.

Conventional control of a softener, the authors state, is by the relationship between the "A" and the "MO" readings. The necessary changes in lime and soda feed are then deduced from empirical rules. After some study it was felt that control could be switched to one based on pH and total alkalinity values. It was immediately recognized that the concept of conductivity could provide further information on the effluent.

The authors then describe the installation of this laboratory study on a practical, full-scale unit.

Boiler Tube Inspection

A symposium of seven papers on instruments for the internal inspection of boiler tubes was presented featuring individuals with considerable experience on the special instruments about which they reported.

J. M. Decker, The Detroit Edison Co., opened with a paper on "The Penetron for Internal Inspection of Boiler Tubes." The Penetron, a product of United Engineers, Inc., Tulsa, Oklahoma, consists of a source of gamma ra-

diation, a radiation-sensitive element and a radiation-measuring device calibrated in such a way that readings can be converted to metal thicknesses. When in use the gamma radiation is directed to the surface of the piece being measured. The amount of radiation transmitted through the piece or back-scattered from the piece is measured. The difference between the radiation directed and the amount measured is indicative of the thickness of the piece.

The instrument in practice is calibrated against samples of known thicknesses and having shapes and compositions similar to the specimen to be measured. A so-called "tangential head" is used for measuring wall thickness of pipes. Radiation passes through the pipe along a chord across the radial section of the pipe. This head must be modified for boiler waterwalls. Since the head and tube surface must be maintained in the same relative position for useful measurements, sand blasting is employed to remove rough slag deposits before measuring. If the tubes are coated with a uniform thickness of scale this cleaning is not necessary.

J. W. Minder, Dayton Power and Light Co., then reported on "The Audigage Inspection of Boiler Tubes." This instrument is a portable, battery-operated, nondestructive device that measures the thickness from one side by determining the resonant frequency of vibration due to the thickness of the material being tested. A vibrating transducer is placed on one side of the test material and is reflected at the opposite surface. At definite frequencies, when the reflected and the transmitted waves are in phase, there will be an increase in amplification of the wave. This increase occurs at a fundamental frequency which is inversely proportional to twice the thickness and directly proportional to the velocity of the sound in the material. By frequency modulating the electronic oscillator, which drives the transducer, a signal is produced at the fundamental frequency and also at the harmonics of the fundamental frequency. This signal may be detected by earphones or by an increase in the deflection of a milliammeter. A conversion scale on the panel indicates the corresponding thickness for a frequency difference between adjacent signals. Again the material under test must be clean of any build-up or scale to give a good ultrasonic coupling. Glycerine or oil are recommended to fill crevices or surface irregularities. Paint, loose scale work adversely. Mr. Minder reported excellent results on inner classifier cones of pulverizers, on coal bunkers, coal chutes, liners, ductwork and also for corrosion or erosion in superheat and reheat sections of the boilers.

"Boiler Tube Inspection with Ultrasonic Resonance Instruments" was presented by **Robert L. Holliday,** R. L. Holliday Co. The device Mr. Holliday described is the Vidigage, a portable, direct reading, resonance type instrument using continuous ultrasonic waves transmitted into the part from one side. The instrument consists essentially of a self-excited oscillator with means for changing the frequency by tuning either the capacitance or the inductance. When the oscillator sweeps over a resonant frequency there will be an increase in the plate current which is displayed by deflecting the trace on a cathode ray tube. The trace shows up as one, two, three or four lines depending upon the thickness of the metal being tested. A plastic scale covering the appropriate thickness range is inserted in the front of the instrument to interpret these lines. The tube surface must be free of scale and adherent fly ash so an electric or air-driven sanding disk is used if the area under measurement is small. Sand blasting is employed for many, large area measurements. Mr. Holliday then described the instrument's behavior in cases of internal corrosion or pitting, internal grooving and external erosion from fly ash.

"The Immerscope Ultrasonic Testing For Boiler Tube Corrosion" by **Robert C. McMaster,** Automation Instruments, Inc., followed. With this device the test material is probed by a very short train of high-frequency sound waves generated by a crystal transducer excited by a suitable electrical impulse. The sensitivity and reliability of ultrasonic inspection of boiler tubes is improved, Mr. McMaster claims, by the use of a specially designed contour transducer which causes the incident sound beams to enter the tube metal surfaces perpendicularly at all points.

J. C. Brown, American Cystoscope Makers, Inc., presented a paper on the Borescope, a precision-built, optical system employing a complex system of prisms, achromatic and plain lenses through which light is passed to an observer. A light source placed in front of or ahead of the objective lens provides illumination for the part under inspection. The brightest images are obtained with Borescopes of large diameters and short length. As the length increases the image becomes less brilliant due to light losses.

A. M. Guy, Southern Indiana Gas and Electric Co., reported on the "Turner Scale Thickness Indicator." This piece of equipment consists of a measuring probe or head and an indicating meter. The probe in current use consists of a nonmagnetic casing inside of which is a compact magnetic coil surrounding a soft iron magnetic core. Attached to the core near each end are two case-hardened steel sliding contacts which engage the surface being measured. Opposite these sliding contacts on the nonmagnetic casing spring-mounted plastic wheels are placed to aid in movement of the probe along the metal's length and at the same time apply a uniform pressure upon the contacts. A graduated flat spring steel tape permits pushing or pulling the probe through any length boiler tube. An insulated flexible two-conductor electrical cord connects the probe to the indicating meter box. This box indicates the thickness of scale, film or deposits in thousandths of an inch. The probe is inserted inside the tube with the attached contacts so arranged that when an alternating current passes through the winding of the coil, the path of a portion of the magnetic flux is through the tube between the probe head contacts.

"The Metroscope As an Aid in Evaluating the Internal Condition of Steam Generators" was related by **J. H. Born, Jr.,** Foster Wheeler Corp. In Mr. Born's report the Metroscope was described as being developed in the shops for a tube-testing device and its use as a maintenance weapon came later. The unit employs a piezo crystal and a system of sonic impulses. The author confined most of his report to application problems urging, for example, the use of glycerine to improve the contact and similarly suggesting cleaning procedures as a preparation for the surfaces about to be tested. The standard Metroscope requires a minimum cable length between crystal and electronic system of 3 to 4 ft and a maximum of about 6 ft. The maximum rate of crystal travel is from 1 to 2 fpm.

REVIEW OF NEW BOOKS

Any of the books here reviewed may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N. Y.

1—Statistical Mechanics

By Terrell L. Hill

432 pages *$9.00*

This book, written for graduate students and research workers in theoretical chemistry and physics, summarizes the principles of statistical mechanics at an intermediate level, and presents an organized and detailed account of certain applications of statistical mechanics which have been worked out since about 1940.

The overall aim of the author in selecting these applications has been to report the most important recent advances that have occurred and to treat each of these in great detail, rather than to give a necessarily superficial account of every topic in the entire field. Emphasis is on the theory of the applications, not on numerical calculations.

2—Maintenance Engineering Handbook

By L. C. Morrow

1528 pages *$20.00*

The long years of first-hand familiarity with the field of maintenance engineering gained by the author as chief editor of *Factory Management and Maintenance* and more recently as general chairman of the National Plant Maintenance and Engineering Conference is reflected in the selection of some 75 individual experts to cover various of the techniques, methods and procedures held by them to be most helpful in keeping production at maximum levels and yet exercising control over production costs and losses.

The bulk of the book is made up of information relative to the selection, installation, and upkeep of the kinds of equipment and services that plants must deal with; electrical, mechanical, and service equipment, transportation equipment, maintenance stores, instruments and instrumentation, and welding. In addition the author attempts to give the reader an insight into the management as well as operative phases of maintenance work.

3—Manual on Industrial Water

ASTM Special Technical Publication No. 148-B, 502 pages, $6.00

This, the third and latest printing of the Manual on Industrial Water, is as always extremely welcome and a value to industry at large. Sponsored by ASTM Committee D-19 on Industrial Water, the Manual contains a complete appendix in addition to a comprehensive discussion of water, its uses, treatment, sampling, analysis and difficulties caused by it.

The appendix lists ASTM standards relating to industrial water. It contains five methods of sampling, 41 standards, four methods of analysis, three standards for methods of reporting results, six standards for methods of test, a glossary of terms, a list of industrial water requirements and a bibliography.

Included in the latest printing are seven new methods and one important revision. Two additional proposed methods are published as additional information.

4—Corrosion: A Compilation

By Dr. Mars G. Fontana

Dr. Mars G. Fontana, chairman of the department of metallurgical engineering at Ohio State University, has authored a monthly column on corrosion during the past ten years for *Industrial and Engineering Chemistry*. This book is a compilation of those columns. The articles are grouped into seven chapters (1) Nature and Extent, (2) Eight Forms of Corrosion, (3) Eight Methods for Combatting Corrosion, (4) Corrosion Testing and Evaluation, (5) Materials, (6) Environments, and (7) High Temperature Oxidation.

Practically all metals and alloys and some non-metallics used for corrosion applications are covered. The book describes methods and detailed procedures for laboratory and plant testing, and shows corrosion as a function of temperature and concentraion of acids through iso-corrosion charts.

5—Applied Metallurgy for Engineers

By Malcolm S. Burton

407 pages *$7.50*

A prior knowledge of metallurgy is not required of the reader and the author follows this approach with a treatment essentially non-mathematical. Yet the book does provide, in a single volume, a combined coverage of physical metallurgy and industrial metallurgical processes presently available. Emphasis, though, is on the background of metallurgical science essential for proper utilization of metallurgical manufacturing methods. A good balance between theory and engineering practice is achieved; diagrams and photographs of equipment implement the theory and relate it to specific manufacturing methods.

The purpose of this book, according to the author, is twofold: to develop the metallurgical principles involved in casting, metal working, welding, heat treatment, and powder metallurgy; and to study these manufacturing processes from an engineering viewpoint, including the metallurgical factors that control selection of suitable processes and the influence of the processes on the final products so as to provide information valuable in school laboratory as well as larger production applications.

6—High Pressure Technology

By Edward W. Comings

572 pages *$11.50*

This publication, one of McGraw-Hill's series in chemical engineering, is the first book to cover the whole field of high pressure technology, and to present the subject at a level that can be understood by a senior student of chemical engineering. Its author is professor of chemical engineering and head of the School of Chemical and Metallurgical Engineering, Purdue University. The central theme is the influence of elevated pressure on chemical and physical systems, and on the design of equipment for handling these systems experimentally or on a commercial scale. Extensive appendices supply data for problems, calculations, and design. A glossary of unusual words and terms is included.

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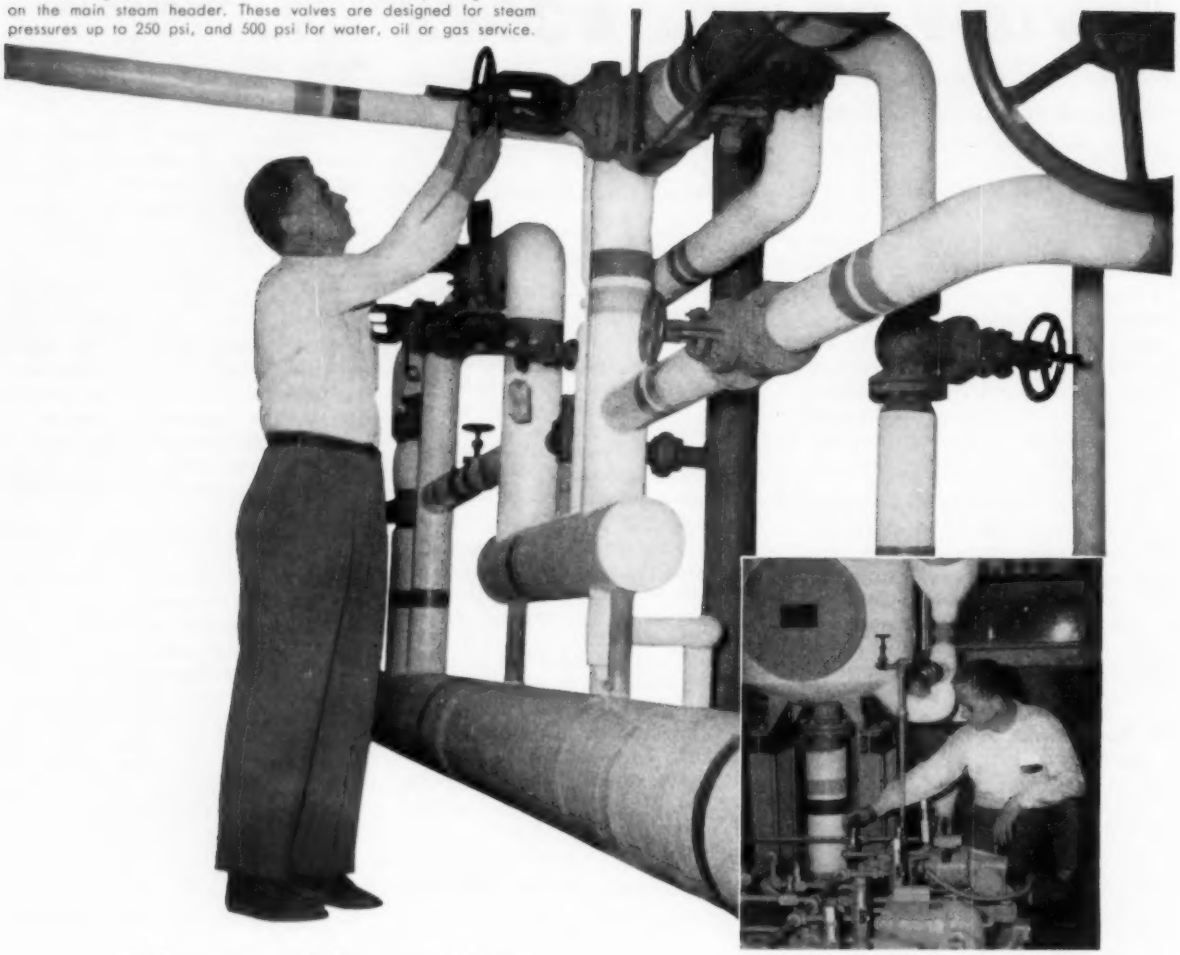

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The Costs of Scrubbing Out SO_2 from Flue Gases*

By J. H. FIELD, L. M. BRUNN, W. P. HAYNES, and H. E. BENSON

Bureau of Mines†

The Federal Government, by Public Law 159, authorized the Department of Health, Education, and Welfare to conduct research on air pollution. This study of the cost of removing sulfur dioxide from flue gases by existing liquid-scrubbing processes has been prepared by the Bureau of Mines in cooperation with the Department of Health, Education, and Welfare as a part of the air-pollution program.

RISING consumption of fuels of relatively high sulfur content, especially in heavily populated areas, has caused growing concern over the possibility of air pollution by sulfur dioxide.

Three liquid-absorption processes for removing SO_2 from flue gases using, respectively, a limestone slurry, ammonia liquor, and a solution of sodium sulfite, were chosen for a cost comparison study. These processes have been used either commercially or have been studied thoroughly on a pilot-plant scale. The cost figures established by this estimate study will enable later comparisons with other processes being considered for SO_2 removal.

Removal of the SO_2 from a coal-burning power plant of 120,000 kw capacity was chosen as a base case. A low-sulfur coal of 1.5 weight per cent and a high-sulfur coal of about 5 weight per cent are considered. Coal consumption of one lb per kwhr was used, the hourly coal requirement being 60 tons. The flue-gas volume was assumed to be 20,000,000 standard cu ft per hr, with SO_2 concentrations of 0.083 and 0.30 per cent for the low- and high-sulfur coals, respectively. Recently constructed power plants operate more efficiently and use less fuel and excess air than the values considered in this estimate. Obviously the removal of SO_2 in such plants would be more favorable, because the quantity of flue gas and sulfur compounds emitted is lower than those shown for the same generation capacity.

Cost estimates have been made for removing 90 per cent of the SO_2 from gases of both concentrations and also for 70 per cent removal from the gas of 0.30 per cent SO_2 content. While it may be unlikely that flue gases with concentrations of less than 0.10 per cent of SO_2 would require purification, an estimate has been included for the low SO_2 content, because data are available for a commercial British plant employing the limestone process at these conditions.

The Nonregenerative Limestone Process

The nonregenerative limestone process was the first non-effluent process used on a commercial scale to lower the SO_2 content of flue gas to extremely low limits.

The commercial plant using limestone was operated by Howden-ICI in Engiand to remove about 90 per cent of the SO_2 from flue gas containing 0.1 to 0.2 per cent of this component. Application of the limestone process at the Fulham power station proved it to be highly efficient, (1).[1] SO_2 is removed from the gas by a neutralizing reaction with a slurry containing about 5 to 10 per cent of limestone or lime as shown by the equations:

$$CaCO_3 + SO_2 \rightarrow CaSO_3 + CO_2 \qquad (1)$$

$$CaO + SO_2 \rightarrow CaSO_3 \qquad (1\text{-a})$$

$$CaSO_3 + {}^1/_2\, O_2 \rightarrow CaSO_4 \qquad (2)$$

Lime is the preferable material because it is usually more reactive, but in most instances the higher cost of lime makes its use prohibitive. Both calcium sulfite and calcium sulfate are formed by the reaction of SO_2 with limestone, and a sludge containing these materials, as well as some ash, is discharged from this process. This sludge is a waste product and is disposed.

A schematic flowsheet of the limestone process is shown in Fig. 1. Flue gas at 120 C passes through distribution chambers to the scrubbing towers, which are connected in parallel. The towers contain wooden grids to provide

* Presented at the 50th Annual Meeting of the Air Pollution Control Association held at St. Louis, Mo., June 2-6, 1957. Under the title "Cost Estimates of Liquid-Scrubbing Processes For Removing Sulfur Dioxide from Flue Gases."

† Central Experiment Station, U. S. Dept. of the Interior, Bruceton, Penna.

[1] Numbers in parentheses refer to List of References appearing at the end of the article.

TABLE VIII—SUMMARY OF COSTS OF SCRUBBING SO_2 FROM FLUE GAS* OF POWER PLANT OF 120,000-KW CAPACITY

	SO_2 Content of Flue Gas Before Scrubbing, Vol. %					
	0.083		0.30			
	90% Removal		90% Removal		70% Removal	
Total investment†						
Limestone process	$1,646,750		$1,992,200		$1,747,200	
Ammonia process	3,221,100		4,945,400		4,055,400	
Sodium sulfite process	2,433,000		3,105,800		2,633,100	
Annual operating costs,‡ $/ton coal consumed						
	No Credit for Products	Credit for§ Products	No Credit for Products	Credit for§ Products	No Credit for Products	Credit for§ Products
Limestone process	1.24	. .	1.93	. .	1.69	. .
Ammonia process‖	2.99	1.62	6.54	1.43	5.38	1.41
Sodium sulfite process	2.10	1.97	3.21	2.17	2.75	1.91

* 475,000 tons/year coal consumed; sulfur content of 1.5 and 5%, respectively.
† Including working capital at 10% of fixed capital.
‡ No provision for return or interest on investment.
§ Ammonium sulfate at $32.00/ton; sulfur at $28.00/ton; SO_2 at $14.00/ton. (Sulfuric acid equivalent price.)
‖ Anhydrous ammonia charged at $100.00/ton delivered.

TABLE I.—NONREGENERATIVE LIMESTONE PROCESS—CAPITAL COSTS

	—SO_2 Content of Raw Gas, Vol. %—		
	0.083	0.30	
	90% Removal	90% Removal	70% Removal
Major equipment installed	$ 537,250	$ 649,450	$ 569,450
Piping	268,500	325,000	285,000
Instruments	18,900	22,800	20,000
Electrical	18,900	22,800	20,000
Mechanical handling	10,800	13,000	11,400
Yard improvements	37,600	45,500	39,900
Buildings	112,200	136,800	120,000
Miscellaneous	40,300	48,600	42,600
General utilities and facilities	40,300	48,600	42,600
Physical Plant Cost	$1,084,750	$1,312,550	$1,150,900
Engineering and construction*	282,10	341,100	299,400
Contingency	130,200	157,500	138,100
Fixed Capital	$1,497,050	$1,811,100	$1,588,400
Working capital	149,700	181,100	158,800
Total Investment	$1,646,750	$1,992,200	$1,747,200

* Includes field indirect costs, engineering, overhead and purchasing, and contractors' fee.

TABLE II.—AMMONIACAL LIQUID PROCESS—CAPITAL COSTS

	—SO_2 Content of Raw Gas, Vol. %—		
	0.083	0.30	
	90% Removal	90% Removal	70% Removal
Major equipment installed	$1,066,390	$1,637,240	$1,342,700
Piping	501,200	769,000	630,000
Instruments	37,325	57,300	47,000
Electrical	37,325	57,300	47,000
Mechanical handling	21,330	32,800	26,900
Yard improvements	74,650	114,800	94,100
Buildings	223,940	343,800	282,000
Miscellaneous	79,900	122,800	100,900
General utilities and facilities	79,900	122,800	100,900
Physical Plant Cost	$2,121,960	$3,257,800	$2,671,500
Engineering and construction*	551,700	847,100	694,600
Contingency	254,600	390,900	320,600
Fixed Capital	$2,928,300	$4,495,800	$3,686,700
Working capital	292,800	449,600	368,700
Total Investment	$3,221,100	$4,945,400	$4,055,400

* Includes field indirect costs, engineering, overhead and purchasing, and contractors' fee.

good contact of gas and liquid with a minimum of pressure drop. The gas leaves the scrubbers at 50 C and fans are employed to overcome the loss of head resulting from the scrubbing operation. A slurry of pulverized limestone is pumped to the top of the absorbers, flows downward countercurrent to the gas, and is passed to delay pits. The slurry is held here to permit the growth of crystals. Overflow from the delay tanks is returned to the absorbers after makeup limestone is added. The more concentrated slurry leaving the bottom of the delay tanks flows to cone thickeners and rotary filters in which a sludge of calcium sulfite and sulfate is separated for disposal.

Ammoniacal Liquor Process

The reaction of ammonia and sulfur dioxide in flue gas results in the formation principally of ammonium sulfate with small amounts of the sulfite, bisulfite and thiosulfite formed. The principal reactions are:

$$2NH_3 + H_2O + SO_2 \rightarrow (NH_4)_2SO_3 \quad (1)$$

$$NH_3 + H_2O + SO_2 \rightarrow NH_4(HSO_2) \quad (2)$$

$$(NH_4)_2SO_3 + {}^1/_2\,O_2 \rightarrow (NH_4)_2SO_4 \quad (3)$$

Absorption towers are similar to those used in the limestone process, and the design of these towers was based upon the information given by Rees of the British Electricity Authority (2). As shown in Fig. 2, two stages of scrubbing are provided to prevent excessive loss of ammonia, the second stage operating with a more dilute solution than the first. A bleed stream of spent solution from the absorbers is processed in the product recovery system. The major portion is recycled to the absorber after the required amount of fresh ammonia has been added. The bleed stream is treated with sulfuric acid in an autoclave at 200 psi pressure and about 360 F. About 90 per cent of the SO_2 removed is recovered in the form of ammonium sulfate and the remaining 10 per cent as free sulfur. After the ammonium sulfate solution leaves the autoclave, it flows to evaporators and crystallizers, where solid ammonium sulfate is recovered.

Regenerative Sodium Sulfite Process

The characteristic features of the sodium sulfite process follows.

(1) SO_2 is removed from the flue gas by countercurrent scrubbing with a solution containing sodium sulfite and bisulfite. Sodium bisulfite is the major product, but some sulfate ion is formed by reaction of sodium sulfite with oxygen in the flue gas.

(2) A slurry of calcium sulfite is added to the spent solution to remove the sulfate ion by the formation of insoluble calcium sulfate.

(3) After the spent solution is desulfated, it is treated with zinc oxide to form a solution of sodium sulfite and a precipitate of zinc sulfite. The sodium sulfite is returned to the absorber, while the zinc sulfite is filtered off, dried, and calcined to recover SO_2 and regenerate zinc oxide for reuse. If sulfate ions were present in the spent solution, losses of zinc would occur by the formation of soluble zinc sulfate.

The various steps of the process are illustrated by the flowsheet given as Fig. 3, and its operation briefly described as follows: absorption of SO_2 occurs in the scrubber by means of the following reaction:

$$H_2O + SO_2 + Na_2SO_3 \rightarrow 2NaHSO_3$$

The sodium bisulfite content of the spent liquor depends upon the amount of SO_2 absorbed. A slurry containing calcium sulfite is added to the spent liquor in a clarifier. The spent liquor contains a small amount of fly ash, most of which is removed by settling in the ash clarifier. Underflow from the clarifier, consisting of a slurry of ash and calcium sulfite and sulfate, flows to a gasifier where SO_2 is added to convert the sulfite to soluble calcium bisulfite,

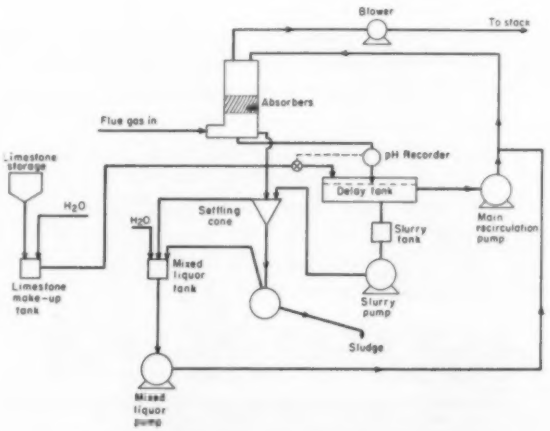

Fig. 1—SO_2 removal by the nonregenerative limestone process

TABLE III—SODIUM SULFITE PROCESS—CAPITAL COSTS

	SO_2 Content of Raw Gas, Vol. %		
	0.083	0.30	
	90% Removal	90% Removal	70% Removal
Major equipment installed	$ 830,410	$1,060,090	$ 897,980
Piping	348,770	445,240	377,150
Instruments	29,060	37,100	31,430
Electrical	29,060	37,100	31,430
Yard improvement	58,130	74,210	62,860
Building	174,380	222,620	188,580
Insulation	8,300	10,600	8,980
Miscellaneous	62,300	79,500	68,100
General utilities and facilities	62,300	79,500	68,100
Physical Plant Cost	$1,602,710	$2,045,960	$1,734,610
Engineering and construction*	416,750	532,000	451,000
Contingency	192,300	245,500	208,100
Fixed Capital	$2,211,760	$2,823,460	$2,393,700
Working capital	221,200	282,300	239,400
Total Investment	$2,433,000	$3,105,800	$2,633,100

* Includes field indirect costs, engineering, overhead and purchasing, and contractors' fee.

$$CaSO_3 + H_2O + SO_2 \rightarrow Ca(HSO_3)_2$$

Ash and calcium sulfate are filtered from the solution of calcium bisulfite, which is treated with lime to form calcium sulfite for another cycle of desulfation.

Clarified spent liquor goes to a mixer, where the proper amount of zinc oxide is fed. While in the mixer, zinc oxide is dispersed in the solution, and then the insoluble zinc sulfite begins to form. Crystallization of hydrated zinc sulfite is completed in an agitated crystallizer by the reaction

$$ZnO + 2\ NaHSO_3 + 1.5\ H_2O \rightarrow ZnSO_3.2.5\ H_2O + Na_2SO_3$$

The hydrate of zinc sulfite is filtered, dried, milled, and calcined and finally returned to the mixer as zinc oxide. The filtrate separated from the zinc sulfite slurry constitutes the regenerated liquor and is pumped back to the absorber for further removal of sulfur dioxide.

Hot gaseous SO_2 and water vapor leave the calciner and are cooled in the liquefaction plant. The condensed water is returned to the agitated crystallizer. Part of the cooled SO_2 gas is sent to the gasifier and the rest is liquefied for shipment.

This process is essentially self-contained. Makeup chemicals are required primarily as a result of sulfite oxidation, spray losses at the scrubber, and dust losses from the calciner and drier. The presence of hydrogen chloride or oxides of nitrogen in the flue gas causes loss of zinc and other reagents by formation of soluble chlorides and nitrates. Lime input is stoichiometrically equal to the waste calcium sulfate; zinc oxide is used to replace the dust losses; sodium carbonate replaces the salts lost in the absorber spray.

Capital Costs

Capital costs were obtained by estimating the installed costs of the major equipment and assigning to each factors for piping, instrumentation, and other items based upon whether the material processed was solid or fluid. Installed costs of the major items were estimated from the data of Aries and Newton (3), Chilton (4), and Nelson (5). Factors of 1.3 and 1.1 were used to translate costs from 1949 and 1954, respectively, to 1956. The following information was used as a basis for estimating the capital costs: The general design basis, flowsheets, material balances, heat and energy balances, utility requirements, equipment lists and specifications, and a general layout of the units. Estimates based on these factors are considered to range from plus or minus 20 per cent of the true cost (6). However, since the same general assumptions were used for cost estimation for each of the three processes, it is believed that comparative error among the estimates is within plus or minus 5 per cent.

The capital costs for the three processes are shown in Tables I, II, and III for the various cases of removal. The investment costs are lowest for the limestone process, ranging from $1,646,750 to $1,992,200, and are highest for the ammonia process, varying from $3,221,100 to $4,945,400. Those of the sodium sulfite process are intermediate and are lower than those of the ammonia process because only one stage of absorption is required. No by-product recovery system is required for the limestone process, and accordingly its capital costs are less than those of the other processes. The plant investment of $1,646,750 for purification of the gas of low SO_2 concentration by the limestone process can be compared with an estimate of £165,900 ($795,000) made by the British in 1932 (7). Since plant costs have risen two- to three-fold in that time, the present-day equivalent might be approximated at about $2,000,000.

Operating Costs

Annual operating costs of the three processes were computed from the utility and chemical requirements shown

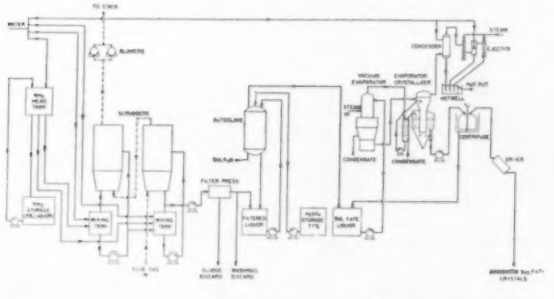

Fig. 2—Ammoniacal liquor process for removal of SO_2 employs two stages of scrubbing to prevent excessive loss of ammonia. The major portion of spent solution is recycled to the absorber after adding ammonia. The bleed stream is treated with H_2SO_4.

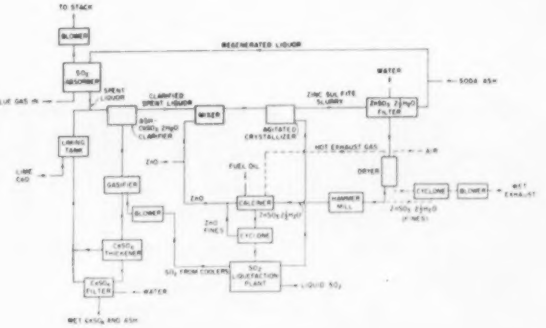

Fig. 3—Regenerative sodium sulfite process for the removal of SO_2 has the scrubber absorb the SO_2. A slurry containing calcium sulfite is added to the spent liquor and the process is then underway.

TABLE V—NONREGENERATIVE LIMESTONE PROCESS—ANNUAL OPERATING COSTS

(330 Days Operation)

	SO_2 Content of Raw Gas, Vol. % — 0.083 — 90% removal	— 0.30 — 90% removal	— 0.30 — 70% removal
Direct Costs			
(a) Raw materials			
Power	$ 34,600	$ 40,800	$ 32,000
Fresh water	7,750	8,850	7,250
Limestone	104,050	378,000	295,000
	147,050	427,650	334,250
(b) Direct labor 4 men/shift at $2.25/hr/man plus supervision	90,700	90,700	90,700
(c) Plant maintenance			
Labor	62,400	72,000	67,100
Materials	36,800	40,900	38,100
(d) Payroll overhead	28,400	30,100	29,200
(e) Operating supplies	14,900	16,900	15,800
Total direct costs	$380,250	$678,200	$575,150
Indirect Costs	102,500	110,300	105,900
Fixed Costs			
Taxes and insurance	29,800	36,200	34,950
Depreciation	74,800	90,500	87,000
Total operating costs	$587,500	$915,200	$803,000
Cost, $/ton coal consumed	1.24	1.93	1.69
Cost, mills/kwhr	0.62	0.87	0.85

The tables V, VI, VII, represent the operating cost figures for the SO_2 scrubbing processes under study

TABLE VI—AMMONIACAL LIQUID PROCESS—ANNUAL OPERATING COSTS

(330 Days Operation)

	SO_2 Content of Raw Gas, Vol. % — 0.083 — 90% Removal	— 0.30 — 90% Removal	— 0.30 — 70% Removal
Direct costs			
(a) Raw materials			
Steam	$ 46,800	$ 170,200	$ 132,800
Power	60,100	63,900	50,000
Fresh water	10,320	18,990	14,780
Circulated water	7,690	27,700	21,600
Anhydrous ammonia liquor	509,000	1,830,000	1,425,000
Oleum	36,300	130,800	101,800
	$ 670,210	$2,241,590	$1,745,980
(b) Direct labor 5 men/shift at $2.25/hr/man plus supervision	113,300	113,300	113,300
(c) Plant maintenance			
Labor	97,420	101,710	99,500
Materials	97,420	101,710	99,500
(d) Payroll overhead	39,000	39,800	39,300
(e) Operating supplies	29,450	31,200	29,800
Total direct costs	$1,046,800	$2,629,310	$2,127,380
Indirect costs	168,800	174,000	171,100
Fixed costs			
Taxes and insurance	58,500	89,900	73,700
Depreciation	146,200	214,600	184,500
Total operating costs	$1,420,300	$3,107,800	$2,556,700
Cost: $/ton coal consumed mills/kwhr	2.99 1.50	6.54 3.27	5.38 2.69

in Table IV, the estimated labor requirements, and the capital costs. Yields of by-products also are shown in Table IV.

Annual operating costs of the three processes are listed in Tables V, VI, and VII. Included in the direct costs are utilities and chemicals consumed, direct labor, plant maintenance, payroll overhead (18.5 per cent of payroll), and operating supplies (15 per cent of maintenance). Indirect costs are charged at 50 per cent of operating labor, direct supervision, plant maintenance, and operating supplies. Fixed costs consist of taxes and insurance at 2 per cent and depreciation at 5 per cent of the fixed capital.

The following charges have been made for utilities and chemicals:

Power	$ 0.0055	per kwhr
Fresh water	0.10	per 1000 gal
Circulating water	0.03	per 1000 gal
Steam	0.37	per 1000 lb
Fuel oil	0.073	per gal
Limestone	6.00	per ton delivered
Anhydrous ammonia	100.00	"
Oleum	35.00	"
Sodium carbonate ($Na_2CO_3 \cdot H_2O$)	63.40	"
Lime	15.00	"
Zinc oxide	305.40	"

The operating costs of $1.24 to $1.93 per ton of coal consumed for the limestone process are the lowest in all three cases if no credit for by-products is allowed for the ammonia and sodium sulfite processes. A comparison summarizing the operating and investment costs is shown in Table VIII, p 61. This comparison is aided by the use of Figs. 4 and 5, in which the capital and operating costs of the processes are illustrated by bar graphs. If the ammonium sulfate and sulfur produced in the ammonia process can be credited at their market prices at the end of 1956 of $32.00 and $28.00 per ton, respectively (Table IX), the operating costs of the ammonia process become the lowest for purification of the gas containing 0.30 per cent SO_2. The operating costs of the sodium sulfite process for purification of the gas of high SO_2 content approach those of the limestone process when the by-product SO_2 is credited at $14.00 per ton. The market price of liquefied SO_2 is about $90.00 per ton, because of the extremely limited demand for this material, but the SO_2 has been credited at a value equivalent to sulfur at $28.00 per ton. As shown in Table IX, the highest by-product credit can be obtained if sulfuric acid is recovered as the by-product.

Extreme caution must be used in allowance for by-

TABLE IV—UTILITY AND CHEMICAL REQUIREMENTS AND YIELD OF BY-PRODUCTS*

	Limestone Process			NH_3 Process			Sodium Sulfite Process		
SO_2 content of flue gas, vol. %	0.083	0.30	0.30	0.083	0.30	0.30	0.083	0.30	0.30
Removal, %	90	90	70	90	90	70	90	90	70
Steam, lb/hr	0	0	0	16,000	58,000	45,200	4,430	27,300	21,300
Water, gal/hr, fresh	9,760	11,160	9,130	13,020	23,970	18,670	19,200	75,900	59,100
Power, kwhr	795	936	735	1,380	1,465	1,150	325	419	330
Fuel oil, gal/hr	0	0	0	0	0	0	184	433	338
Chemicals, lb/hr									
Limestone (95% $CaCO_3$)	4,400	15,900	12,400	...	...	...	...	...	...
Anhydrous NH_3	...	...	...	1,284	4,620	3,600	...	...	...
20% Oleum	...	...	...	262	945	735	...	...	...
$NaCO_3$	...	...	...	...	...	...	309	309	241
ZnO	...	...	...	...	...	...	29.7	70.0	63.1
Lime	...	...	...	...	...	...	1170	1170	913
Yield of by-products, tons/day									
Ammonium sulfate	...	...	...	59.7	215.5	167.8	...	...	...
Sulfur	...	...	...	4.63	16.7	13.0	...	...	...
Sulfur dioxide	...	...	...	...	...	...	16.1	99.6	77.9

* Quantities for treating 20,000,000 SCFH flue gas.

TABLE VII—SODIUM SULFITE PROCESS—ANNUAL OPERATING COSTS

	—SO_2 Content of Raw Gas, Vol. %—		
	0.083	0.30	
	90% Removal	90% Removal	70% Removal
Direct costs			
(a) Raw materials			
Power	$ 17,750	$ 22,850	$ 18,000
Fresh water	19,000	75,000	58,500
Steam	16,000	98,700	77,000
Fuel oil	133,000	302,700	238,750
Sodium carbonate	90,900	90,900	70,900
Lime	69,400	69,400	54,100
Zinc oxide	35,900	84,700	76,300
	$ 381,950	$ 744,250	$ 593,550
(b) Direct labor 5 men/shift at $2.25/hr/man plus supervision	113,300	113,300	113,300
(c) Plant maintenance			
Labor	77,500	99,000	84,000
Materials	77,500	99,000	84,000
(d) Payroll overhead	35,200	39,300	36,500
(e) Operating supplies	23,200	29,700	25,200
Total direct costs	$ 708,650	$1,124,550	$ 936,550
Indirect costs	145,800	170,500	153,000
Fixed charges			
Taxes and insurance	44,200	56,500	47,900
Depreciation	110,800	141,200	120,000
Total operating costs	$1,009,400	$1,492,800	$1,257,500
Cost: $/ton coal consumed	2.13	3.15	2.65
Mills/kwhr	1.07	1.58	1.33
Dollars/ton of liquid SO_2 produced.	185.5	42.3	44.3

TABLE IX—MARKET PRICES OF SULFUR PRODUCTS, 1956*

Product	Dollars/ton	Dollars/ton Sulfur Equivalent
Sulfur	28.00	28.00
Sulfuric acid (100%)	23.50	71.90 (3.06 tons)
Ammonium sulfate	32.00	24.70 (3.94 tons)‡
Sulfur dioxide, gas	14.00†	28.00 (2 tons)

* *Chemical and Engineering News*, Prices, 4th quarter, 1956.
† Computed as sulfur equivalent.
‡ Corrected for 1.015 tons of ammonia required at $100.00/ton delivered.

TABLE X—CAPITAL CHARGE ON TOTAL INVESTMENT ($/TON COAL CONSUMED)

	Capital Charge, %		
	6	9	12
Limestone process:			
0.083% SO_2 in gas	0.21	0.31	0.42
0.30% SO_2 in gas			
90% removal	0.25	0.38	0.50
70% removal	0.22	0.33	0.44
Ammoniacal liquid process:			
0.083% SO_2 in gas	0.41	0.61	0.81
0.30% SO_2 in gas			
90% removal	0.62	0.94	1.25
70% removal	0.51	0.77	1.03
Sodium sulfite process:			
0.083% SO_2 in gas	0.31	0.46	0.62
0.30% SO_2 in gas			
90% removal	0.39	0.59	0.78
70% removal	0.33	0.50	0.67

products, especially in the case of ammonium sulfate. The total quantity of ammonium sulfate produced from ammonia in 1955 (1,131,106 tons) (8) would be obtained from only 16 power plants of 120,000 kw capacity in which 90 per cent of the SO_2 was removed from a flue gas containing 0.30 per cent of this material. On the other hand, allowance of by-product credit for sulfur and SO_2 is less speculative. Approximately 90 per cent of the sulfur produced or recovered in various forms eventually is converted to sulfurous and sulfuric acid, with SO_2 the intermediate product (9). The SO_2 recovered from the flue gas of a 120,000 kw power plant would be equivalent to only one-three hundredth of the 1955 consumption of 15,800,000 tons of sulfuric acid.

General Considerations

In general, the capital requirement for a power plant burning coal would be increased 10 to 20 per cent by the addition of scrubbing facilities. The operating costs per ton of coal consumed vary from about $1.25 to $2.00, allowing credit for products and for the ammonia and sodium sulfite processes would be appreciably higher, with no by-product credit allowed. This amounts to operating costs from about 0.6 to over 1 mill per kwhr of power generated, without charge on the capital investment. Actually, the cost of the coal consumed to generate power amounts to only 2 to 3 mills per kwhr, with the cost of coal in the $4.00 to $6.00 per ton price.

No allowance has been made in these estimates to pro-

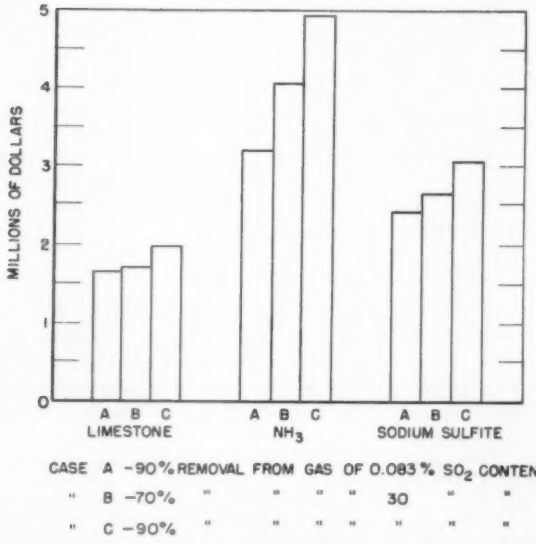

Fig. 4—Capital cost of SO_2 removal processes are presented in bar form above. The fact that the ammonia process needs two stages for absorption weighs heavily in final costs

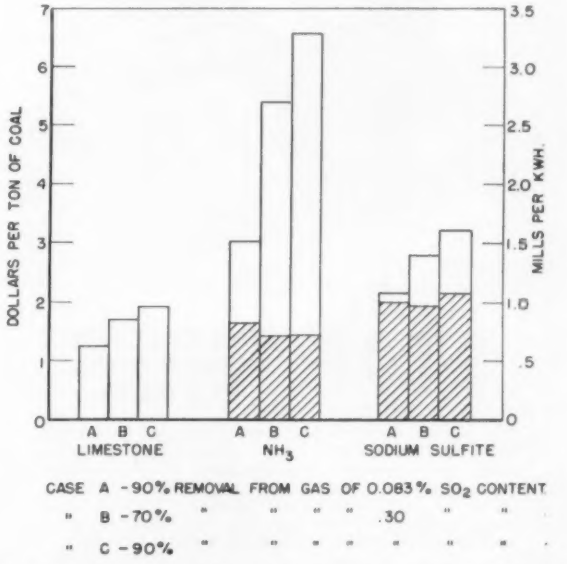

Fig. 5—Operating cost of SO_2 removal processes. Top of shaded areas show net cost after allowing by-product credit

vide for capital charges. These will vary, depending upon the method by which the plant is financed. The capital charges for the various plants at rates of 6, 9, and 12 per cent are shown in Table X. For a charge of 6 per cent, the cost of SO_2 removal would be increased from $0.21 to $0.62 per ton of coal above the costs shown in Table VIII, p. 61.

Although the costs of these purification processes reflect an appreciable increment per ton of coal consumed or power generated, they are consistent with the costs to be expected for the type of chemical operations involved. Undoubtedly improved process techniques can effect significant reduction in the cost of removing SO_2 from flue gases. Purification processes operating at normal flue gas temperatures would have advantages both cost-wise and from a technical point of view. After purification the hot gases would be discharged in the usual fashion and disperse readily, whereas, when the flue gas is cooled, additional power is required to discharge it, and there is the possibility of rapid settling and localized pollution by the residual sulfur dioxide. Pollution due to this cause has actually occurred at a power station in England where liquid scrubbing was employed (10).

Other desirable features to achieve cost reduction are:

(1) Use of absorbents that are readily reactivated for reuse with minimum replacement.

(2) Recovery of the SO_2 in a convenient form for sulfuric acid production rather than in some less valuable form or as a waste product for which no credit can be obtained.

(3) Development of a simple process scheme for both purification and by-product recovery to reduce capital costs. However, regardless of the amount of cost reduction achieved by improved processes, necessarily there will be additional capital outlay and operating costs to remove SO_2 from flue gases. These costs will have to be added to the cost of power generation and may be justified by the advantages of cleaner air.

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(10) See Reference (1) above.

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Urge Unity of Engineers

By 1980, Louis R. Howson, president of the American Society of Civil Engineers, told his society's annual convention that the United States will have more than 1,250,000 practicing engineers. Of engineers receiving degrees from 1900 to 1950, some 529,000 were living in 1953 and two-thirds of these were still practicing. "It is estimated the American economy now needs to add about 30,000 engineering graduates per year, a figure which is about 5,000 more than the number now being graduated," said Mr. Howson.

Mr. Howson stressed his belief that Engineers Joint Council offers the best assurance of unity in the engineering profession that has been witnessed in the last hundred years. Further, the best interests of the profession will be served if EJC is given an adequate, honest opportunity to demonstrate its value to the profession.

Unity in the profession as Mr. Howson sees it must be primarily for the purpose of promoting the general welfare of mankind through the available resources and creative ability of the engineering profession rather than to enhance the stature of any particular engineering organization. It is believed EJC has made marked strides along this line.

At the same time Mr. Howson took office as president of the ASCE the following men were also installed:

Vice-presidents: Waldo G. Bowman, of New York, Editor of *Engineering News-Record*, and Samuel B. Morris, of Los Angeles, former general manager of the City of Los Angeles Department of Water and Power and a consulting engineer. They will serve two years.

Abstracts From the Technical Press—Abroad and Domestic

(Drawn from the Monthly Technical Bulletin, International Combustion, Ltd., London, W.C. 1)

STEAM GENERATION AND POWER PRODUCTION

Steam Generators

The Optimum Position of the Last Superheater Stage. R. Dolezal. *Mitt. V.G.B. No. 47, 1957, (Apr.) 95–101. (In German.)*

The trend in recent years has been to place the last superheater stage in the region of higher flue gas temperature, e.g. in the passage between the furnace and the convection pass. Calculations are developed to show that there is in fact an optimum position both with regard to non-uniform distribution of the flue gas temperature over the width of the pass and non-uniform distribution of steam temperature in the superheater coils. Simultaneously the advantages and disadvantages of parallel and counter flow of gas and steam have been investigated; it is concluded that the last stage should preferably be in parallel flow since this results in a more uniform steam temperature. Counter flow is preferred for the first superheater stage where the non-uniformity of the gas temperature is greater and the steam temperature still low.

Solid Fuel Firing

New Stokers for Brown Coal Firing. W. Boie. *BWK 1957, 9 (May) 226–7. (In German).*

The development of a new stoker is described in which the grate bars make a swinging reciprocating movement so that the fuel bed is broken up and loosened. Air compartments under the grate are unnecessary because the free grate area can be varied according to the properties of the fuel to be burnt. The burning-out grate is separately actuated hydraulically so that the ash can be accumulated until it is completely burned out. Caking coals, fine coals, briquettes and breeze can be fired by the stoker. The stoker is available in various sizes for boilers of 3000 to 16,000 lbs/h capacity.

Liquid and Gaseous Fuel Firing

Mixing Coefficients of the Furnaces of Oil Fired Steam Generators. H. Fritsch. *Energie 1957, 9 (Apr.) 117–25. (In German.)*

Theoretical and practical investigations into the combustion process of oil flames in furnaces are reported and the influence on the mixing of oil droplets and air of burner design (flame structure), number of burners, furnace heat release rate and furnace dimensions are discussed. The calculation of a mixing coefficient is developed which characterises the quality of the mixture obtained; this coefficient should be about 10 for small central heating boilers and increase to 100 or more for large industrial boilers.

Water-Side Corrosion and Water Treatment

Sodium Silicate and Free Silicic Acid Content in Superheated Steam of Once-through Boilers at 110 atm. Y. U. M. Kostrikin, Yo. O. Novi, G. I. Aleinikov and V. A. Taratuta. *Teploenergetika 1957, 4 (Apr.) 37–40. (In Russian.)*

Tests for determining sodium silicate and free silicic acid content, carried out under conditions corresponding to the generation of steam in once-through boilers at 110 atm and superheated steam temperatures of 420–430 C, show that where Na_2SiO_3 is present in the feedwater in concentrations of or exceeding 0.03–0.04 mg/kg SiO_3^{2-}, the SiO_3^{2-} in the superheated steam (temperature range in the tests was 360–430 C) will not depend on the velocity of the medium or the initial concentration, but will remain constant, equalling 0.03–0.04 mg/kg. The deposits in this case will contain not only Na_2SiO_3 but other sodium silicates as well. When the Na_2SiO_3 content in the feedwater is below this value, the silicic acid concentration in the steam will equal the silicon content of the feedwater.

Behaviour and Regeneration of Ion-exchange Resins used for Treatment of Boiler Feedwater. F. F. Ross. *Washington: B.C.S.O.(N.A.) Report 1957, No. 1117 (Feb. 18) 8pp.*

Cation exchange resins can be damaged by heavy metals and oxidizing agents; strong base anion resins become fouled by organic substances present in some waters. Pre-treatment of water, arrangement of exchange units to avoid trouble, and methods of restoring capacity are referred to, as well as methods of testing water before design of full-scale plant. Water of adequate quality for boiler pressures up to 1250 psi can be obtained from some raw waters by processes much cheaper than complete demineralisation, particularly if steam washers are installed.

Boundary Layer Processes in Heated Evaporator Tubes. A Critical Consideration of the Theory of Hide-Out. H. E. Hömig. *Mitt. V.G.B. No. 47, 1957 (Apr.) 113–7. (In German.)*

It is shown that the original theory of hide-out of boiler water salts of hide-out of boiler water salts is untenable on thermo-dynamical grounds. It is shown that instead: 1. The primary cause of hide-out is a radial movement of the water towards the tube wall and an accumulation of the salts in a boundary layer near the wall; 2. The radial flow is directly proportional to the heat release rate of evaporation; 3. The salts are returned to the water by diffusion, convection and atomisation; 4. The ratio of salt concentration in the boundary layer and boiler water can be expressed by an approximate equation; 5. The temperature of the boundary layer is above the boiling temperature and the salt concentration effects a further increase of the boiling point so that the temperature rises still further; 6. All salts are separated in this layer the solubility of which is exceeded at that temperature but not all salts separated out in solid state are returned to the boiler water and may thus disappear from it.

Corrosion Studies in High Temperature Water by a Hydrogen Effusion Method. M. C. Bloom, M. Krulfeld, W. A. Fraser and P. N. Vlannes. *Corrosion 1957, 13 (May) 27–32.*

Corrosion rates of low carbon steel in distilled water at 600 F, the effect of raising the pH in the system, of thermal shock and of temperature rise and the effect of heat treatment of the metal have been studied. Corrosion rates of low carbon steels and stainless steels are compared.

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Gas-Side Corrosion and Deposits

Ammonia or Dolomite Process? A. Upmalis. *BWK. 1957*, **9** (*May*), *232*. (*In German.*)

The ammonia process for reducing SO_3 corrosion of convection heating surfaces was tried out some years ago in Scandinavia where it was injected into the flue gas at a temperature of 750 F. A hard layer formed on the surfaces which could not be removed by sootblowing or steel-sand blasting. Water washing caused interruption of operation and other difficulties so that the process was abandoned and the dolomite process substituted. The dolomite is ground to 20 microns and injected above the oil burners. The deposits on the heating surfaces are loose and easily removed by sootblowing. Dolomite consumption is about 1 per cent of oil consumption. In plants operated previously without dolomite the dew point was reduced within three months of applying dolomite from 285 to 140 F.

"Terlite." Anon. *Coll. Guard. 1957*, **194** (*May 16*), *645–6*.

A plant for the utilisation of the fly ash produced at Battersea power station making light-weight aggregate for the building industry is described. The ash is first pelletised and passed to a kiln in which the carbon remaining in the ash is consumed, all sulphur at 1 400 C. The sintered pellets are graded into $^3/_8$-, $^3/_8$-, and $^3/_{16}$ in. sizes. The concrete made with Terlite is light but strong and its moisture movement and drying shrinkage very low, about 0.025 per cent.

Power Generation and Power Plant

Results of Operation of Once-through Boiler Installation of the V.T.I. at 300 atm and 600 C. K. A. Rakov and N. V. Bulgakova. *Teploenergetika 1957*, **4** (*Mar.*) *22–26*. (*In Russian.*)

An account is given of the results obtained from the operation of this boiler and its auxiliary equipment from 1949 to 1955, during which period it was fired with fuel oil for 5300 hours and by pulverised coal for 15,000 hours. The behaviour of the boiler materials is also analysed.

Investigation of the Working Process on the V.T.I. Experimental Once-through Boiler at Supercritical and Extra High-pressures. K. A. Rakov and N. V. Bulgakova. *Teploenergetika 1957*, **4** (*Apr.*) *21–28*. (*In Russian.*)

The paper presents the results of a study of the thermal conditions of heating surfaces, diffusion of the heat picked up and the hydrodynamic characteristics of this experimental boiler at pressures of 180–300 atm.

Power Station Buildings. C. Bottrell. *Electr. Rev. 1957*, **160** (*May 10*), *849–51.*

Figures are given to show the decrease in building volume required per kW installed by the use of larger units. Different ways of arranging the boilers and turbines are discussed to obtain the lowest overall volume commensurate with providing sufficient room for access and repairs.

Condenser Tubes are Welded. R. A. Wilson and W. W. Edens. *Elect. World 1957*, **147** (*Apr. 22*) *57–8.*

A method of welding non-ferrous condenser tubes into tube sheets has been developed by Allis-Chalmers Manufacturing Co. The tungsten inert gas process with D.C. proved the best together with an over-riding high frequency A.C. initiating the arc and starting the weld. The combination of tube and sheet material found applicable to this process are stated.

Materials Aspect of Some High Temperature Refinery-Piping Applications. E. A. Sticka. *Trans. A.S.M.E. 1957*, **79** (*May*) *715–9.*

The subject is considered under these headings: 1. Graphitization; 2. Limitation of various carbon steels; 3. Carbon limits for low-alloy casting steels; 4. Service embrittlement of ferritic steels; 5. Welding of chromium-molybdenum steels; 6. 885 F embrittlement in high chromium steels; 7. Experience with austenitic steels.

INSTRUMENTS AND CONTROLS

Measurement of Average Temperatures with Thermocouples. H. J. Löffler. *Chem. Ing. Tech. 1957*, **29** (*May*) *336–9. (In German.)*

Numerical and electrical averaging methods are compared; the former are time consuming, the latter are simpler but produce an additional measuring error. The error in series and parallel installation of thermocouples for measuring average temperature are about the same but the series installation is preferred because: 1. In parallel installations all thermocouples must have the same resistance; 2. In series installations the measurement is independent of thermocouple resistance due to change in temperature if the indicating instrument has a high inner resistance; 3. The voltage to be measured is higher in series circuits when using a compensating circuit.

NUCLEAR ENERGY

Thermo-Nuclear Power. A Theoretical Introduction. W. B. Thompson. *Nature 1957*, **179** (*May 4*) *886–9.*

The physical conditions required for the process of fusing light nuclei and the processes by which these conditions may be realized are discussed. The theoretical and practical difficulties are stressed. All in all the article provides a good basic understanding.

Fast Fission—Its Possibilities, Its Problem. Anon. *Nucl. Pwr 1957*, **2** (*June*) *222–3.*

Atomic Review. Central Core. Anon. *Engineering 1957*, **183** (*May 17*) *634–6.*

The review includes: 1. Euratom Plans: 15,000 MW of nuclear power station construction within a space of 10 years; 2. a German nuclear power plant of 15 MW capacity to be built by Brown Boveri and F. Krupp: this will have a homogeneous, gas-cooled and graphite moderated reactor with ceramic fuel elements of uranium carbide and graphite; reactor control is by changing uranium load and coolant flow; operating temperature will be high enough to generate steam at 980 F; 3. new American projects; those under construction show a very steep rise in costs; 4. the organic moderated reactor (OMRE) using diphenyl as coolant; 5. the sodium reactor experiment (SRE) became critical on May 1; 6. ceramic fuel reactor.

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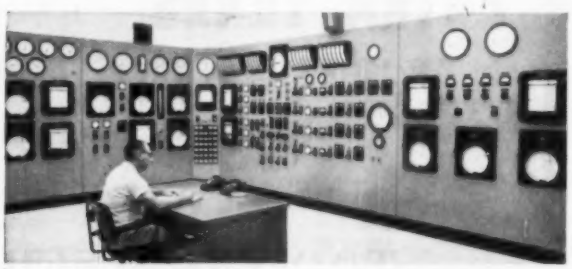
Planned expansion of power in the Southeastern United States is typified by the addition of Unit #3 to South Carolina Generating Co.'s Urquhart Station. Rated capacity of the steam generator is 700,000 lb/hr at 1825 psi, superheated to 1010 F and reheated to 1010 F. Designed by Gilbert Associates, Urquhart #3 is modern in performance as well as appearance.

REPUBLIC's "Electronic Master" combustion control and triple-element feedwater control permit firing of pulverized coal, natural gas, or both at once without fluctuation of header pressure or water level. This system starts adjusting fuel, air and water as soon as steam flow changes perceptibly, not waiting for either drum level or header pressure to change.

If either of these factors change despite the preliminary adjustment, the change will be very small and will be offset immediately by a follow-up control that modulates the existing control signal. Since the flow of flue gas is held in such close proportion to the steam flow, temperature at the superheater outlet is held very close to a constant 1010 F despite load swings.

This advanced control system is a logical partner to the advanced thinking apparent throughout Urquhart #3. The quick action of electronic control added to the traditional reliability and power of pneumatic actuation produces a stable, accurate, dependable automatic system. And any one or all of the automatic control functions can be cut out at will to permit substitution of remote manual control at any time. Manual controls include indicators for electronic loadings of the regulators and positioners as well as position and rate of response indicators.



Control room of Urquhart Station's modern Unit #3.

NEED HELP on "Early Stage" Planning?

Remember that Republic, too, is planning ahead. To get the latest information on developments that will effect control in your future power or processing plant, contact the REPUBLIC Engineering Department as soon as such help would be beneficial.

REPUBLIC FLOW METERS COMPANY

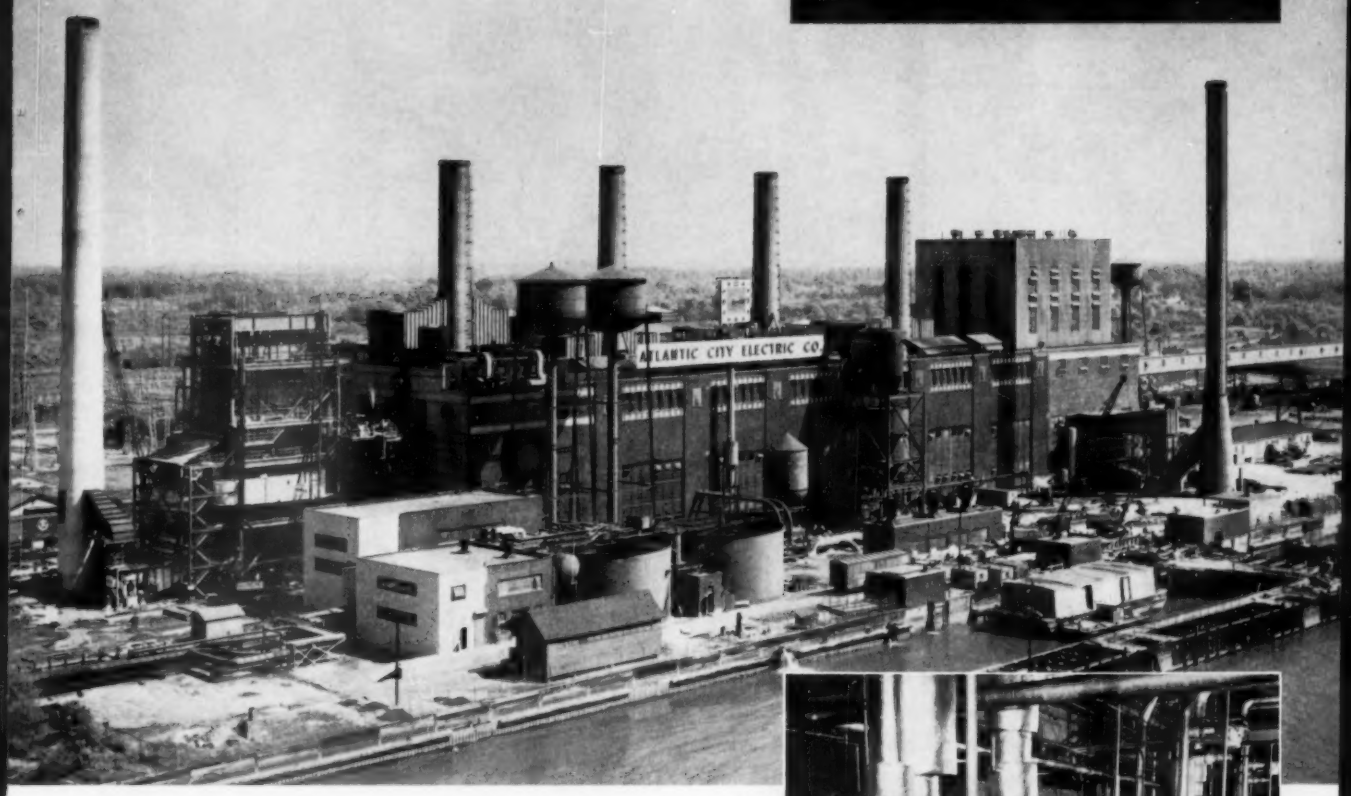
A Subsidiary of Rockwell Manufacturing Company

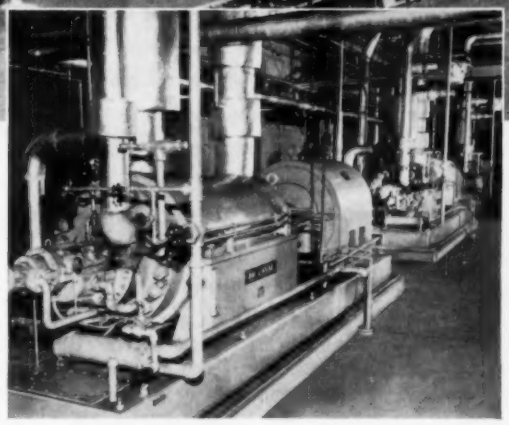
2240 Diversey Parkway, Chicago 47, Illinois

Modern central stations use

DE LAVAL

BARREL TYPE BOILER FEED PUMPS





Three ten-stage De Laval high pressure, barrel type boiler feed pumps, are on the line at the Deepwater Station of the Atlantic City Electric Company. Shown above is an aerial view of this station located in Penns Grove, New Jersey at the southern end of the Jersey Turnpike. Each pump delivers 675 gpm to the boiler for a total flow of 685,000 pounds per hour. Each pump operates at 1762 psi with temperature at 287 F., and is driven by a 900 hp motor.

When it came time to modernize one of their existing facilities, Atlantic City Electric Company and Gibbs & Hill, Inc., consulting engineers, chose two similar De Laval pumps to serve a new 79,000 kw generator.

IMO Pumps For Fuel Oil Service

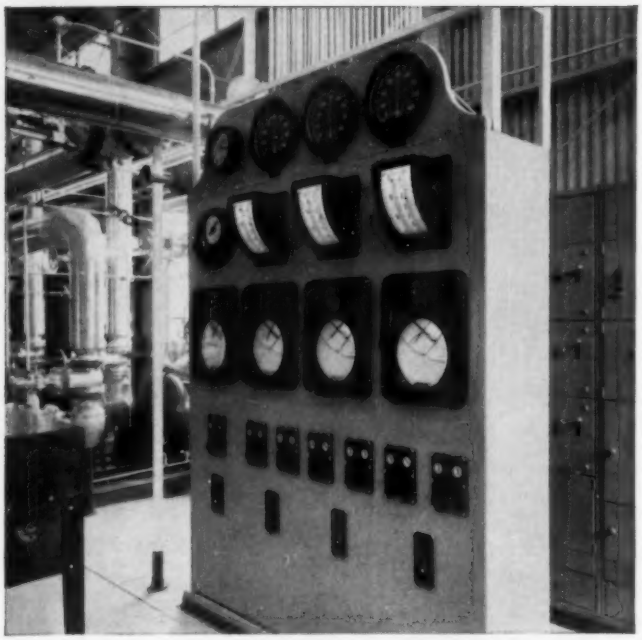
Also doing an important job in this Atlantic City Electric Company station are De Laval IMO screw-type positive displacement pumps. They supply fuel oil to the burners round the clock.

Send for De Laval Bulletin 1506, which contains helpful data.

DE LAVAL *Boiler Feed Pumps*

DE LAVAL STEAM TURBINE COMPANY
886 Nottingham Way, Trenton 2, New Jersey

DL-386



Bailey Boiler Control Panel for three 150,000 lb per hr, 400 psi, gas-fired boilers. Meter at left records total Steam Flow; the other three meters record Gas Flow—Air Flow and Flue Gas Temperature.

How to Control Steam Costs

★ Close regulation of fuel and air input is vital to a strict control of your steam cost. But that's not all. You'll need control of other factors, too. Your costs can be held down only by controlling all of the important operations in your steam plant. That's where you can be sure of help from Bailey Controls. Here's why they can do the job and do it right:

1. Suitable Equipment

When you receive equipment recommendations from a Bailey Engineer his selections come from a complete line of well-engineered and carefully tested products.

2. Seasoned Engineering Experience

Your local Bailey Engineer brings you seasoned engineering experience based on thousands of successful installations involving problems in measurement, combustion, and automatic control.

3. Direct Sales-Service—close to you

For your convenience and to save time and travel expense there's a Bailey District Office or Resident Engineer in or close to your industrial community.

For greater fuel savings, less outage and safer working conditions, you owe it to yourself to investigate Bailey Controls. Ask a Bailey Engineer to arrange a visit to a nearby Bailey installation. We're glad to stand on our record. A-125-1

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for Cutting
Steam Costs
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+ Bailey Design
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= Greater Savings
per Fuel Dollar

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CLEVELAND 10, OHIO
Complete Controls for Steam Plants

BAILEY METERS
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COMBUSTION
FEED WATER
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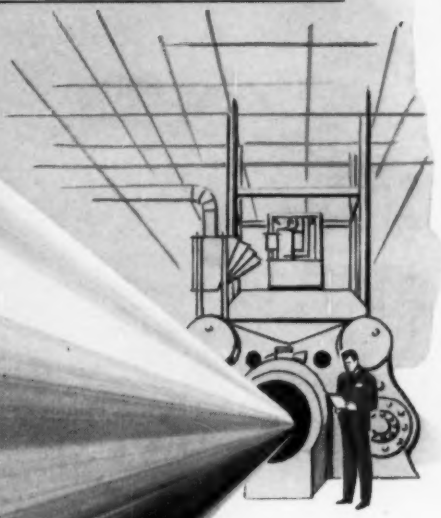
FEED PUMPS

FOR YEARS OF PIPE ECONOMY...



THIS EXTRUDED HEAVY WALL

PROTECTS

against severest heat, pressure and corrosion

Here is High Integrity pipe for the toughest applications in the power, petroleum, chemical and other industries. Extruded from any ferrous alloy in lengths up to 50 feet or more, and with virtually any wall thickness, this pipe from the Curtiss-Wright Metals Processing Division provides increased on-the-job life, long-term economy, elimination of down time – not just for months, but for years to come. Extruded to specification under tremendous one-push pressures from the Division's giant 12,000-ton horizontal steel extrusion press, Curtiss-Wright Heavy Wall Pipe is of uniform high strength and has high resistance to pressure, heat and corrosion. Write today for information on both your standard and special requirements.

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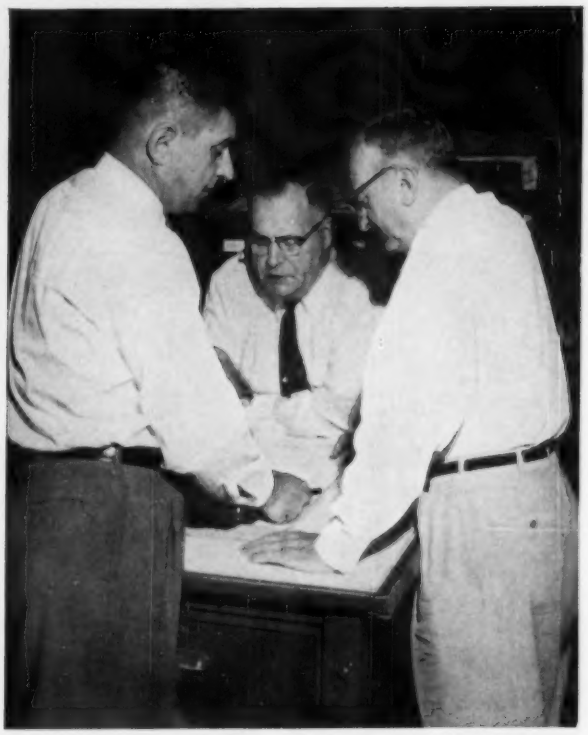
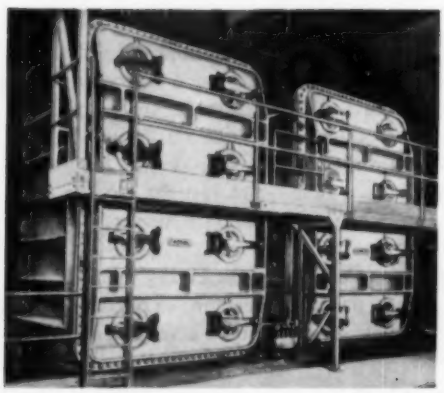
Before you place your next order...

It's saved many weeks, even months of engineering and executive time for scores of power companies! Basically, the idea is to shift as much of the work load as possible from the customer to C.H. Wheeler. By working this way, long conferences are replaced by short phone calls, and lengthy customer-prepared engineering specifications are supplanted by thumbnail performance sheets.

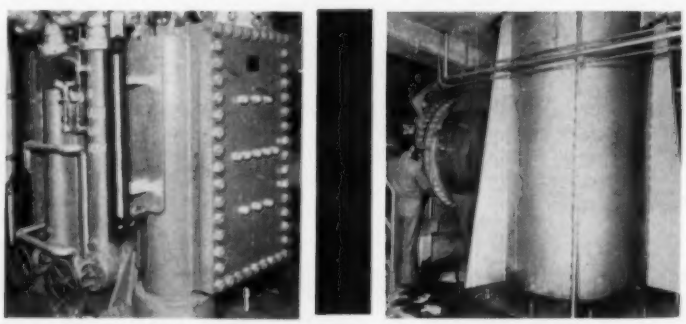


Since Wheeler specializes in designing and building condensing equipment, its Engineering Department is set up to take this bare minimum of data from the customer, and work up a comprehensive proposal from it alone. Here you see several department heads of C. H. Wheeler discussing engineering design prior to preparing a proposal for a C. H. Wheeler client.

Discover C. H. Wheeler's time-saving way to buy steam condensers



We often save clients up to 4 months' time by sending Wheeler engineers to work "on the board" at clients' offices, instead of mailing drawings for approval. Above is a typical installation—a 105,000 sq. ft. Dual Bank Divided Water Box Unit, installed at a New York station.* It condenses 950,000 lbs. steam/hr.



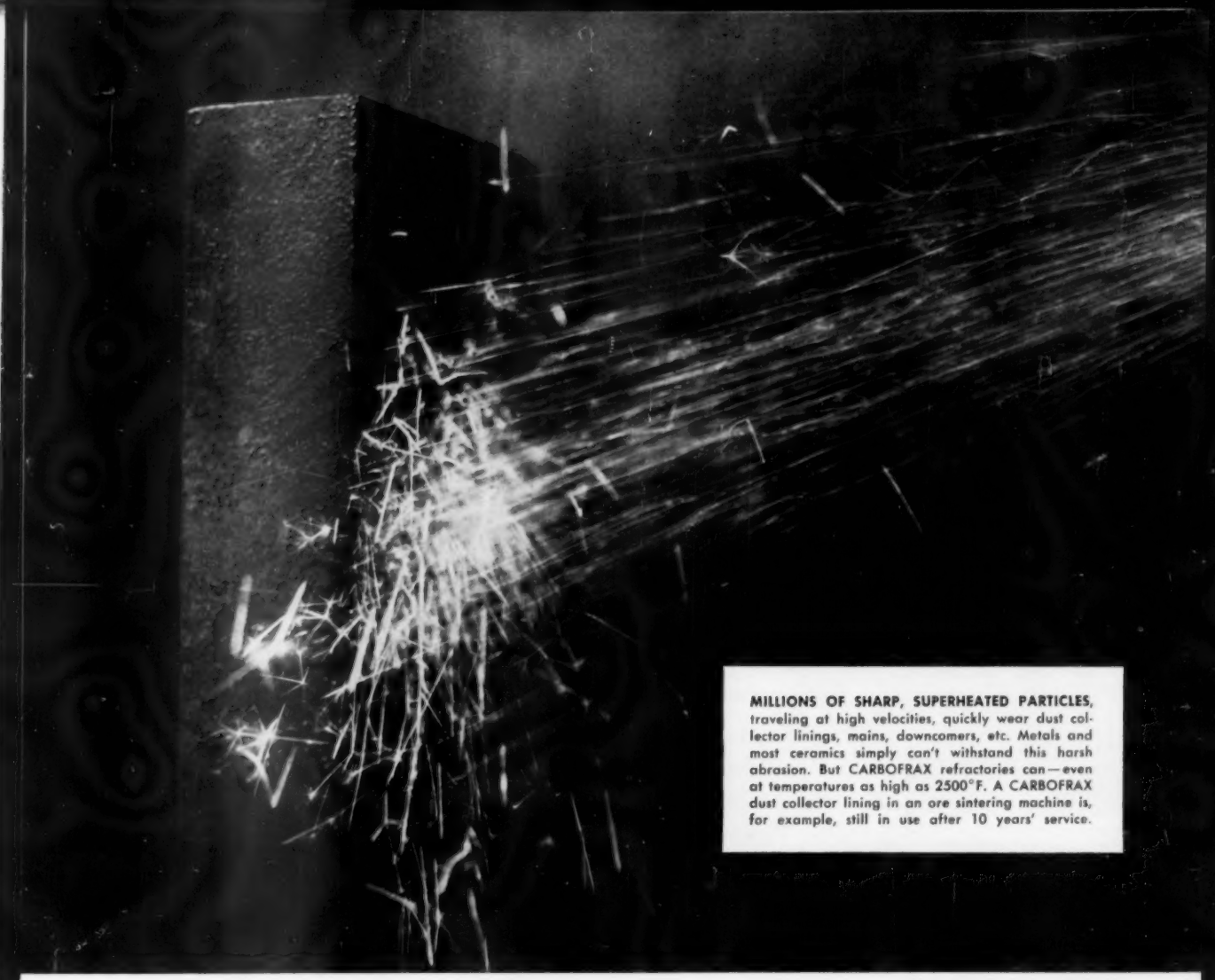
Other C. H. Wheeler power plant equipment includes steel-shell "Tubejet"® Air Ejectors (left) as installed at eastern plant*, Circulators (right) which in the same plant deliver 86,500 gpm water, and Condensate Pumps. See your representative or write for details on the time-saving way to buy Dual Bank Surface Condensers and other power equipment.

**Names of these and other power stations equipped by C.H. Wheeler supplied on request.*

C. H. Wheeler Mfg. Co.

19TH & LEHIGH AVENUE Philadelphia 32, Pennsylvania

Steam Condensers • Vacuum Equipment • Centrifugal, Axial and Mixed Flow Pumps • Marine Auxiliary Machinery • Nuclear Products



MILLIONS OF SHARP, SUPERHEATED PARTICLES, traveling at high velocities, quickly wear dust collector linings, mains, downcomers, etc. Metals and most ceramics simply can't withstand this harsh abrasion. But CARBOFRAX refractories can—even at temperatures as high as 2500°F. A CARBOFRAX dust collector lining in an ore sintering machine is, for example, still in use after 10 years' service.

Refractories . . . to resist abrasion

Exceptional resistance to abrasion—whether caused by tiny gas-borne particles or sliding steel billets—is one of the most useful properties of several of Carborundum's unique refractory materials. For example, when used in the exhaust lines of gasoline catalytic cracking units in temperatures ranging up to 1200°F, these refractories lasted 3 years, as compared to alloy rings which lasted for 6 months.

And when abrasion is combined with higher temperature, the exceptional resistance of these super refractories becomes even more apparent and useful. As skid rails in furnaces which heat 6-lb. billets to 2250°F—pushing 250 slugs an hour—CARBOFRAX® silicon carbide refractories need one-third the replacement, one-third the labor and one-third the down-time of ordinary rammed chrome ore hearths. Other successful applications include: dust collectors, gas scrubbers, transfer pipe lines, hydro cyclones and process equipment parts, to name but a few.

Many applications call for other properties in combination with wear resistance. Among Carborundum's many materials are refractories that also offer excellent heat shock resistance with sufficient hot strength to withstand 25 psi at 3128°F. Others provide unique resistance to corrosion as well as abrasion. These properties are but a few of those to be found in super refractories pioneered by Carborundum. Among them, you are almost certain to find answers to your refractory and high-temperature problems. For help, fill in and mail this coupon:

CARBORUNDUM
Registered Trade Mark

----------MAIL THIS COUPON TODAY----------

Dept. E117, Refractories Division,
The Carborundum Company, Perth Amboy, N. J.

Please send me:

- ☐ Forthcoming issue of Refractories Magazine
- ☐ Bulletin on Properties of Carborundum's Super Refractories
- ☐ Here is a description of my high temperature problem. Can you help me?

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Company _____

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City _____ Zone _____ State _____

PROGRESS IN POWER through PROGRESS IN HEAT TRANSFER EQUIPMENT

Workman welding copper-nickel tubes to foot-thick steel tube sheet with 140-monel electrodes. Under destructive testing, rolled joints and tubes welded with cupro nickel rods leaked at elevated pressures, but tubes welded with 140-monel electrodes were leak-proof at 9600 psi.

End view showing torus ring welded to channel and channel cover. Access to head is obtained by cutting ring with special tool; torus ring can be re-used. Conventional split key ring assembly taking the load on the cover is retained.

FIRST ALL-WELDED FEEDWATER HEATERS

▶ A few years ago, an all-welded feedwater heater for 3600 psi and 790F would have been called a fantastic dream.

Yet six all-welded feedwater heaters in this pressure-temperature range are now proving their worth in the Linden, N. J., Generating Station of the Public Service Electric and Gas Company. Designed and manufactured by the Yuba Heat Transfer Division, formerly the Heat Exchanger Division of The Lummus Co., these heaters represent one of the many "firsts" contributed by this organization to the progress of the power industry.

In the heater shown above, two 50-inch-diameter cylinder sections of 1⅛-inch carbon steel were welded together. The open ends of the U-bends are welded, not roller-expanded, into the tube sheet (see upper small photo). Heads are sealed by a steel torus ring welded to channel cover and channel (see lower small photo).

The all-welded design minimizes the leakage which occurs in the conventional bolted and gasketed construction under high temperatures and pressures. Results are reduced maintenance and downtime.

This all-welded construction has been so successful it is certain to be specified for practically all future installations. Yuba engineers would be pleased to work with you. Call on them.

YUBA

CONSOLIDATED INDUSTRIES, INC.

Other Divisions Manufacturing Heat Transfer Equipment
California Steel Products Division, Richmond, Cal.
Adsco Division, Buffalo, N. Y.

YUBA HEAT TRANSFER DIVISION
HONESDALE, PENNSYLVANIA
NEW YORK SALES OFFICE: 530 FIFTH AVENUE
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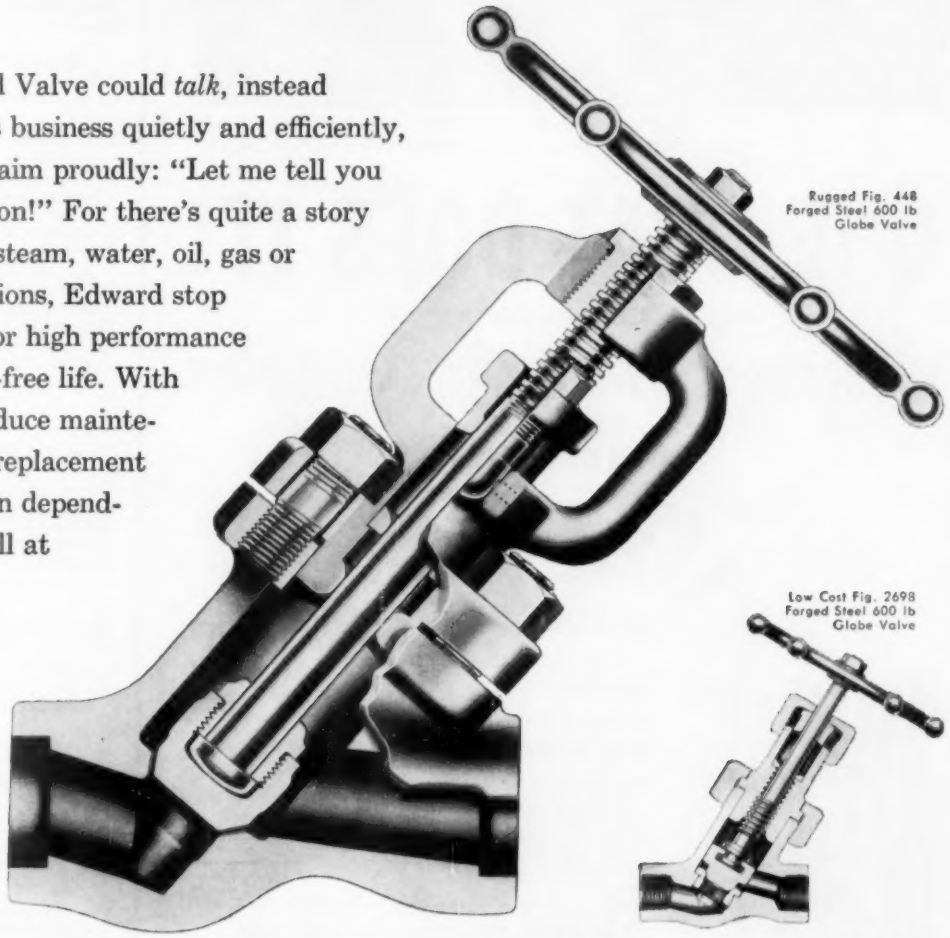
STEAM JET REFRIGERATION • STEAM JET AIR EJECTORS
FEEDWATER HEATERS • BAROMETRIC CONDENSERS

Buying stop valves?

Let me tell you about my operation!

If an Edward Valve could *talk*, instead of going about its business quietly and efficiently, it might well exclaim proudly: "Let me tell you about my operation!" For there's quite a story to be told . . . in steam, water, oil, gas or chemical applications, Edward stop valves are built for high performance and long, trouble-free life. With them, you will reduce maintenance costs, cut replacement inventories, obtain dependable service . . . all at low initial cost.



Rugged Fig. 448
Forged Steel 600 lb
Globe Valve

Low Cost Fig. 2698
Forged Steel 600 lb
Globe Valve

FORGED STEEL body, bonnet, yoke add extra strength to Edward stop valves!

EVALLOY STAINLESS STEM resists corrosion!

STELLITE FACED or EValloy stainless seat and disk last longer.

SWIVEL DISK prevents seat galling!

LARGE HANDWHEEL eases operation!

STAINLESS STEEL SWING GLAND BOLTS aid easy repacking!

POSITIVE BACKSEAT permits packing under pressure!

FOR FULL DETAILS on these and other Rockwell-Built Edward forged and cast steel valves, write for the Edward Condensed Catalog.

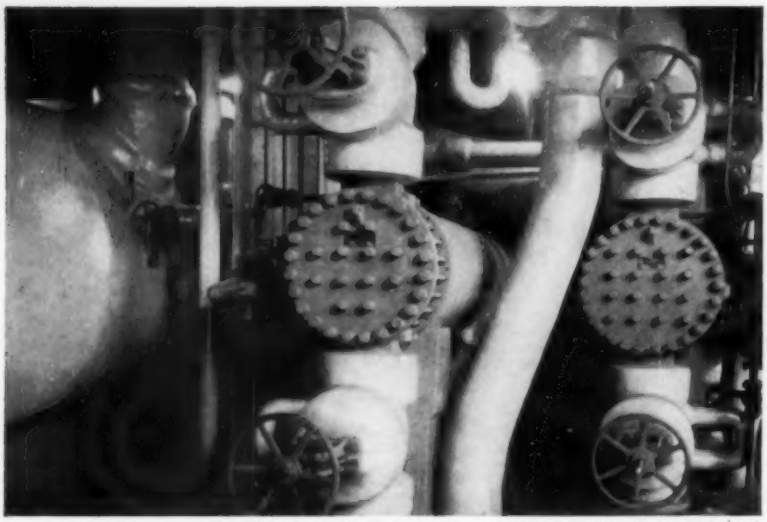
Edward Valves, Inc.

Subsidiary of

ROCKWELL MANUFACTURING COMPANY

1206 WEST 145TH STREET

EAST CHICAGO, INDIANA



Drum head, piping flanges, ells, valves, insulated with Stic-Tite and then troweled to a smooth, white, hard finish with Super Finish Stic-Tite.

ONE COAT DOES IT!

(NO ROUGHING COAT NEEDED)

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INSULATING CEMENT

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INSULATING BLOCK, BLANKETS AND CEMENTS

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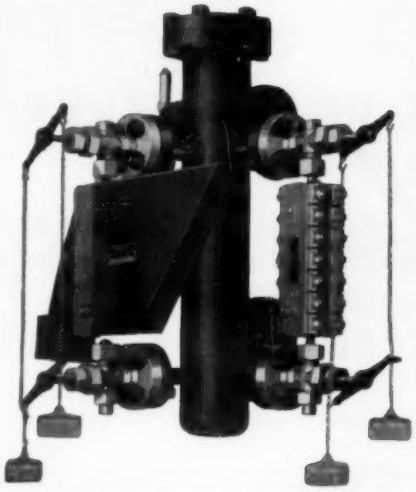
Reliance Boiler Safety Equipment is a profitable investment for your power plant

Don't overlook the relatively *small* equipment that keeps the *big* equipment running smoothly. Reliance Safety Devices are mainly applied to boiler water level supervision, but the well-being of your boilers affects other "big" equipment, as you know. So the selection of high grade accessories for the boilers is of major importance.

Water Columns and Gages are basic equipment you must add to your boiler when installed, or order with it from your boiler maker. Reliance offers you complete service in approved devices for water level supervision, including extra alarm devices that help insure attention of operators if a dangerous water level situation threatens. Reliance representatives in all major cities are ready to help you at any time.

The Reliance Gauge Column Company
5902 Carnegie Ave., Cleveland 3, Ohio



Water Columns for all pressures, with or without alarms.

Water Gage Valves

Gage (try) Cocks

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Water Gage Illuminators

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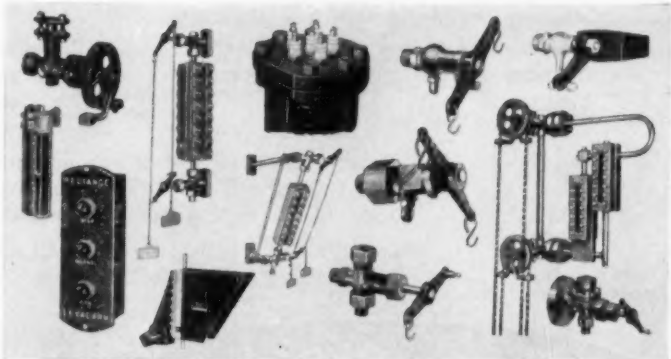

The name that introduced safety water columns....in 1884

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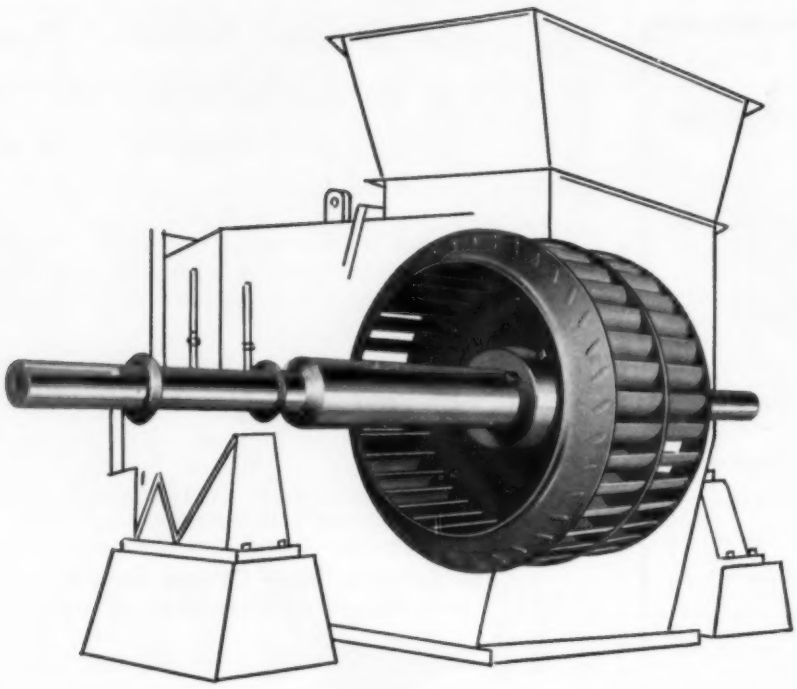
BOILER SAFETY DEVICES



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New Concept

IN INDUCED DRAFT WHEEL DESIGN

36 radially deep, aerodynamically curved blades impart a dynamic energy to the gas stream to achieve low tip speed operation.

Unique shape of the blades and rims minimizes shock losses and turbulence at the entering edge of the blades and between the blades.

Wheel design assures relatively low moment of inertia (WR^2).

Wheel is constructed with a heavy forged steel hub and a sturdy centerplate.

All welded construction of the wheel provides ample shear strength, tensile strength, and rigidity.

These are only a few of the features that make Clarage's new Type DN Dynacurve Fans fully equal to the most punishing demands.

Write today for Bulletin 905. CLARAGE FAN COMPANY, Kalamazoo, Michigan.

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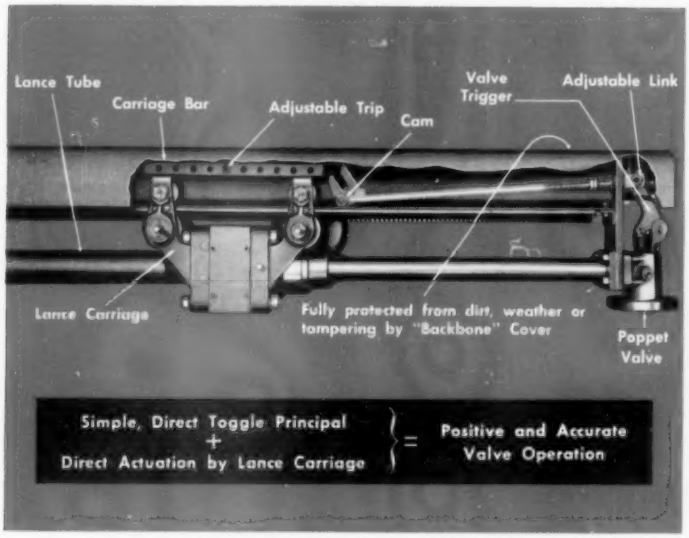
MECHANICALLY OPERATED POPPET TYPE VALVE

(WITH ADJUSTABLE PRESSURE CONTROL)

additional important features of the NEW Diamond Series 300 IK LONG RETRACTING BLOWER



This valve was adopted for the new Series 300 IK because long experience has proved it the most satisfactory of all designs for severe blower service. More than 300,000 of this basic design are in use on various Diamond Blowers and have established notable service records. A recent improvement is more streamlined flow contours that permit higher flow rates with less pressure drop.

The direct mechanical linkage for actuating the valve offers the advantages of greater reliability and safety . . . in addition to more accurate control. Numerous other important features of the Series 300 IK are listed at the bottom of page. These are the reasons why this blower is establishing a new standard of efficiency, economy and dependability in cleaning heating surfaces that require a long retracting blower.

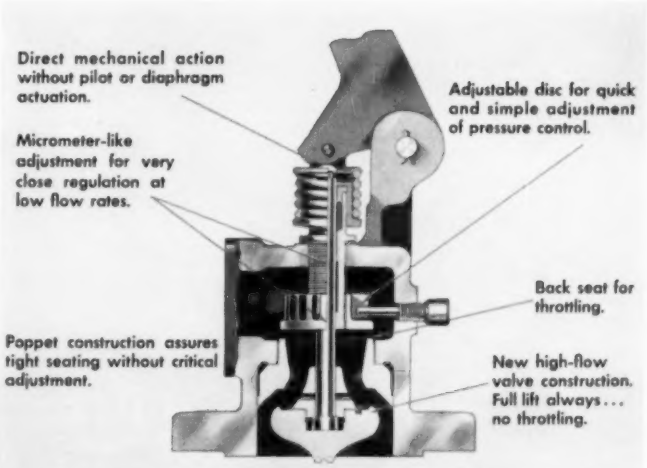
Bulletin 2111V tells much more about the Series 300 IK; ask your local Diamond office or write directly to Lancaster for a copy.

SERIES 300 IK—LONG RETRACTING BLOWER

OTHER ADVANTAGES OF SERIES 300 IK BLOWERS

- Backbone and Protective Cover
- Compact, Accessible Electric Power and Control Terminal Facilities
- Front End Single-Motor Drive
- Nozzle-Sweep-Every-Inch Cleaning Pattern
- Improved "Type A" Nozzle
- Positive Gear Carriage Drive
- Single Point Outboard Suspension
- Oversize Lance (Step-Tapered for Extra Long Travel)
- Auxiliary Carriages for Extra Long Travel
- Designed for Quick, Easy Servicing

No other blower gives you all these advantages.


Direct mechanical action without pilot or diaphragm actuation.
Micrometer-like adjustment for very close regulation at low flow rates.
Poppet construction assures tight seating without critical adjustment.
Adjustable disc for quick and simple adjustment of pressure control.
Back seat for throttling.
New high-flow valve construction. Full lift always . . . no throttling.

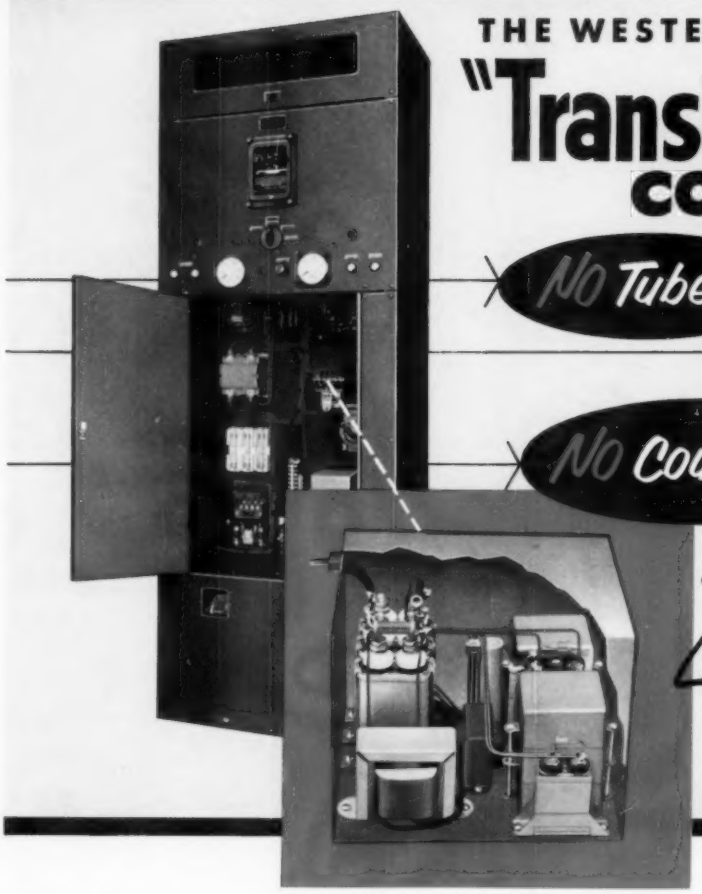
FULL LIFT AND FULL OPENING OF VALVE AT ALL TIMES. No throttling at main seat. ALL throttling for pressure control is between back seat and adjustable disc.

DIAMOND POWER SPECIALTY CORP. LANCASTER, OHIO

Diamond Specialty Limited, Windsor, Ontario

7884

BY FAR, the Industry's Most Advanced Precipitator Control...



THE WESTERN PRECIPITATION "Transistomatic" CONTROL

No Tubes!

No Relays!

No Counters!

and carries a Lifetime Guarantee!

In the electrostatic precipitation of dust, fume and fly ash, no installation is completely modern without *automatic* control to maintain optimum Precipitator efficiency as the characteristics of the gas stream fluctuate. Compared with manual control, automatic control is not only more sensitive and more efficient, but actually costs less because of the vital savings it makes in labor and operating costs . . . *savings so important that no profit-minded operator will want to be without them.*

But the important point to remember is this—

Although many manufacturers of precipitation equipment offer units for precipitator automation, no other unit is equal to the "Transistomatic" Control for foolproof simplicity, rugged dependability or control accuracy!

These are not idle claims. They can be easily verified by making your own comparison . . .

A DESCRIPTIVE BOOKLET

that gives further facts and figures will gladly be sent on request. Write, wire or phone our nearest office!

Compare ACCURACY! The "Transistomatic" does not base its "sensing" action on spark *frequency* alone—or spark *intensity* alone. Instead, it continuously integrates BOTH frequency and intensity to establish an overall "power value" that provides a new standard of control accuracy!

Compare DEPENDABILITY! The "Transistomatic" unit contains no parts of any kind requiring regular replacement. Moreover, the entire unit is completely sealed—moisture-proof and watertight.

Compare GUARANTEES! The "Transistomatic" is so foolproof and trouble-free it carries *a lifetime guarantee!*

BEFORE YOU BUY ANY automatic precipitator control, be sure to get the complete "Transistomatic" story. A folder is available giving facts and figures. Or see your nearest Western Precipitation representative for further details!

WESTERN
PRECIPITATION
CORPORATION

Engineers and Constructors of Equipment for Collection of Suspended Material from Gases . . . and Equipment for the Process Industries

LOS ANGELES 54 • NEW YORK 17 • CHICAGO 2 • PITTSBURGH 22 • ATLANTA 5 • SAN FRANCISCO 4

Representatives in all principal cities

Precipitation Company of Canada Ltd., Dominion Square Bldg., Montreal